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The Object and Scope of A. S. A. E. Activities

THE American Society of Agricultural Engineers was organized in December, 1907, at the University of Wisconsin by a group of instructors in agricultural engineering from several state agricultural colleges, who felt the need of an organization for the exchange of ideas and otherwise to promote the advancement of agricultural engineering. The object of the Society, as defined by the Constitution, is "to promote the art and science of engineering as applied to agriculture, the principal means of which shall be the holding of meetings for the presentation and discussion of professional papers and social intercourse, and the general dissemination of information by the publication and distribution of its papers, discussions, etc."

The membership of the Society represents all phases of agricultural engineering, including the educational, professional, industrial, and commercial fields.

The scope of the Society's activities embraces both the technical and economic phases of the application of engineering to agriculture, and is comprehended in the following general headings:

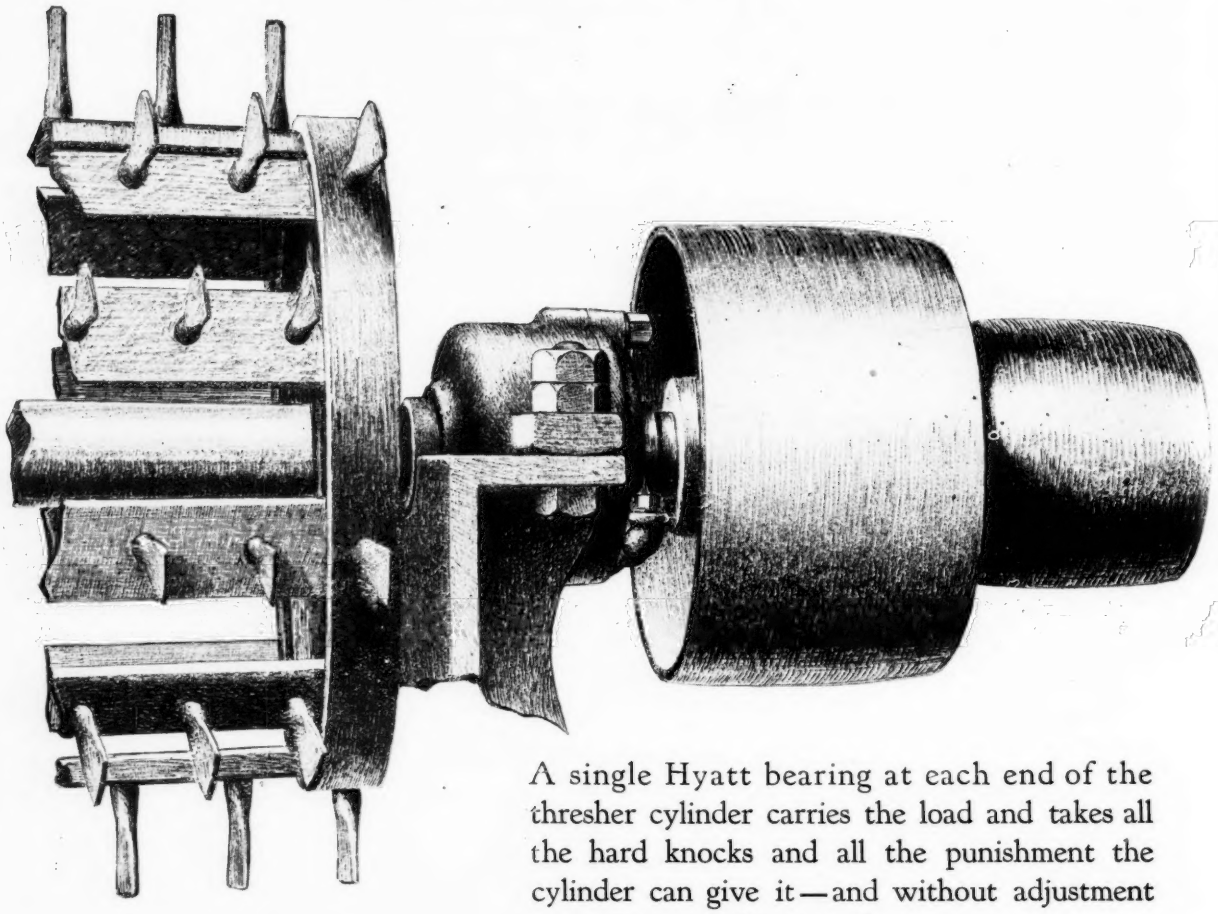
(a) Farm Power and Operating Equipment—power, implements, machines, and related equipment.

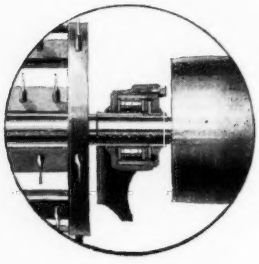
(b) Farm Structures—buildings and other structures and related equipment.

(c) Farm Sanitation—water supply; sewage disposal; lighting, heating, and ventilating of farm buildings, and related equipment.

(d) Land Reclamation—drainage, irrigation, land clearing, etc., and related structures and equipment.

(e) Educational—teaching, extension, and research methods, etc., employed in the agricultural engineering field.





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Vol. 4 JUNE, 1923 No. 6

Experiences in the First Breaking of Peat Lands*

By G. R. B. Elliott
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IN THE spring of 1922 a tract of peat land under the control of the Minnesota agricultural experiment station was being put under cultivation for drainage experimental purposes. Information regarding the equipment necessary for peat land farming is both meagre and conflicting. More particularly is this true with respect to the preliminary operation of breaking and preparing the first seedbed. The opportunity was therefore taken to obtain accurate information regarding the equipment required for the heavier operations and the best method for applying that equipment.

The tract selected was several acres of tamarack swamp drained with tile the previous fall. Peat on the tract was from five to seven feet deep and had carried a very heavy growth of trees, principally tamaracks, birch, elm and maple. So thick were these trees, it was estimated that in the clearing, which took place from April 15 to June 15, fifty cords of stumps to the acre were removed. The holes left by the removal of these stumps and the soft spots left by the back filling of the drains were a very considerable factor in all the cultural operations, more particularly in the first plowing. It was considered that the job was a fairly difficult one, but one that was thoroughly representative of the actual conditions which would have to be met by the farmer in breaking up timbered peat land. During the progress of the experiment the water level was maintained about three feet at the lower end and four feet at the upper end below the surface of the peat. At the upper end of the tract the soil was fairly firm with considerable sod, while at the lower end the peat was very soft and much torn and pitted by the removal of the stumps.

In the first breaking of any land a very important consideration is the getting rid of trash and soft litter. On peat land it is also especially important to plow sufficiently deep to get under the deep underground root stalks of marsh vegetation. A very large proportion of swamp plants are perennials which store food for the next spring's growth in thickened roots or in heavy root stalks deeply buried below the action of frost and ice. The root stalks of nettles, for example, may frequently be found a foot below the surface while cattails may have roots fifteen to eighteen inches deep. The greater number of heavy root stalks, with the exception of those of grass and small sedge, are to be found in the second six inches. Ten inches to one foot is, therefore, about a minimum depth for first plowing under average conditions on peat swamps other than grass marsh, and plows were chosen which would cut effectively to that depth, namely, plows with 16-inch to 20-inch shares. These in their turn required comparatively heavy tractor equipment. In all five types of plows and three types of tractors were used.

Three different types of round-wheel tractors were available. These varied in design, weight, width, operating speed,

(Above) This picture shows the reason for deep plowing of peat soil. The clover in the picture was photographed the latter part of May. It was sowed in the fall on 8-inch plowing after flax. That in the foreground was broken 6 inches deep, and that in the background 12 inches. The peat varied from 4 to 7 feet deep. (Below) The character of the original timber and the stumps taken off

*Paper No. 379, Journal Series, Minnesota Agricultural Experiment Station, December, 1922.

(Above) Tractor bogged down in soft spot. (Below) Team standing in exact spot where tractor bogged down, illustrating the packing and increased bearing power of the peat due to work of reclamation on it

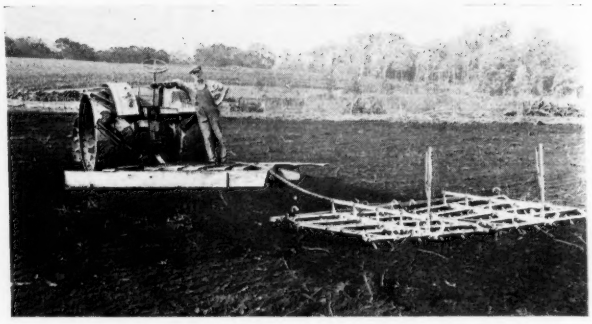
and special equipment. As the type and equipment of the tractors had as much to do with the quality of work done as did the character of plow drawn, the specifications of the tractors and other equipment are given in the accompanying table. For convenience the tractors are named "A," "B," and "C." Similarly the plows are named "X" and "Y" followed by "M" or "B" to indicate whether it was a "marsh" or "breaker" bottom that was being used.

TABLE 1. DETAILS OF TRACTORS

ITEM	Tractor A, 2-plow	Tractor B, 3-plow	Tractor C, 3-plow
Horsepower	18 (belt)	12-25	12-20
Plowing speed—miles per hour, low	1.48	2.25	2.10
Plowing speed—miles per hour, high	2.73	3.00	2.75
Width overall, as equipped —inches	61⅜	84	79
Drivewheel dimensions, standard—inches	42x12	52x12	54x12
Drivewheel dimensions, as equipped—inches	42x12	52x18	54x24
Front wheel dimensions, standard—inches	28x5	28x6	36x6
Weight complete—pounds	2920	6100	5120
Weight on front wheels—pounds	1063	1575	1583
Weight per inch width, front wheels—pounds	106	131	132
Weight on drivewheels—pounds	1857	4525	3352
Weight per inch of width of drivewheels, as equipped —pounds	77.4	125.5	69.83+
Design, wheels on sod or in furrow	furrow	furrow	sod
Position of drawbar offset —inches	1	10	10
Depth of front skid rings, as equipped—inches	1	1½	3
Angle lug spacing—inches	7	10	20
Depth of angle lugs—inches	3½	3	3
Regular involute spade depth—inches			4
Number of teeth between lugs—inches			16

Dynamometer used—Schaffer and Eudenburg Company, 3,000 pound.

Tractor A was available from the beginning but it was



(Above) The character of plowing in the peat ground. (Below) How the finished job looked

felt beforehand that it would not pull the plows, so no attempt was made to use it on this part of the work. The horsepower indicated by the dynamometer readings made with the heavier tractors show this opinion to have been correct. Tractor A, however, was used to help Tractor B by hitching it on in front as will be described.

Tractor B did not come on the ground in all respects properly equipped, and its use cannot be considered a success. It was as powerful as Tractor C and with similar wheel equipment undoubtedly should have done the work just as well. It will be noted that its rear wheels carry a much heavier load per square inch of bearing surface than do either A or C, and its front wheels while carrying the same load per width of face were much smaller in diameter. The depth of skid rings on the front wheels was practically negligible. The material travelled over was very soft and slippery. As a consequence the driver had little control over the direction of his machine, and when the front end plunged into the soft back-fill of a ditch or into the hole left by the removal of a stump, the tractor almost invariably mired and had to be pulled out with the help of Tractor A. Finally Tractor A was kept hitched on ahead by a chain about 15 feet long.

Tractor B was first hitched to a 20-inch "XB" plow and at the instance of the factory operator was tried by running with the two right wheels in the furrow. After much difficulty and miring one length of the field was completed, but the plow was not actually plowing at any time. After this the drawbar of the tractor was pushed as much as possible to the right while the hitch of the plow was thrown to the left. This permitted the tractor to travel on the unplowed ground, but the best furrow that could be cut was about six inches in depth and there was heavy side draft which tended to pull the tractor into the furrow. As there was nothing to prevent the front wheels from skidding this slewing of the tractor was serious. It is probable that by using a chain hitch, as was done later, the side draft could have been partially eliminated.

The greatest trouble was experienced in turning at the ends of the field. The front end of the tractor had no grip on the soft ground, and when a wheel fell into a hole the force of the tractor would drive it still deeper into the far side. In trying to back up much the same thing happened and the rear wheels frequently mired by first cutting up the sod with the closely set angle lugs. It was at this point that Tractor A was hitched on ahead to help in the steering and to prevent Tractor B from getting mired. This arrangement worked quite satisfactorily and the plow cut to a depth of eight to twelve inches. As these were not standard operating methods and as the proper wheel equipment could not be readily obtained to hold up Tractor B, it was decided to discontinue the work in the hope that a tractor could be found with approximately as much power but with less weight per inch of width on the wheels, with the equipment necessary to make it operate successfully, and with drawbar so designed that it would permit the tractor to run on the sod without undue side draft.

We were able to get a tractor which seemed to answer requirements, whose makers were willing to cooperate in the work under way. This is Tractor C.

Profiting by previous experience we asked for 12-inch extensions on the rear wheels, 4-inch extensions on the front wheels, skid rings on the front wheels 3 inches high, angle-iron lugs that would run clear across the face of the rear wheel rim, placed with wide spacing, and 4-inch spade lugs in pairs between the angle lugs. With the tractor used, it was found that owing to the comparatively light weight on the front wheels it was not necessary to use the 4-inch extensions.

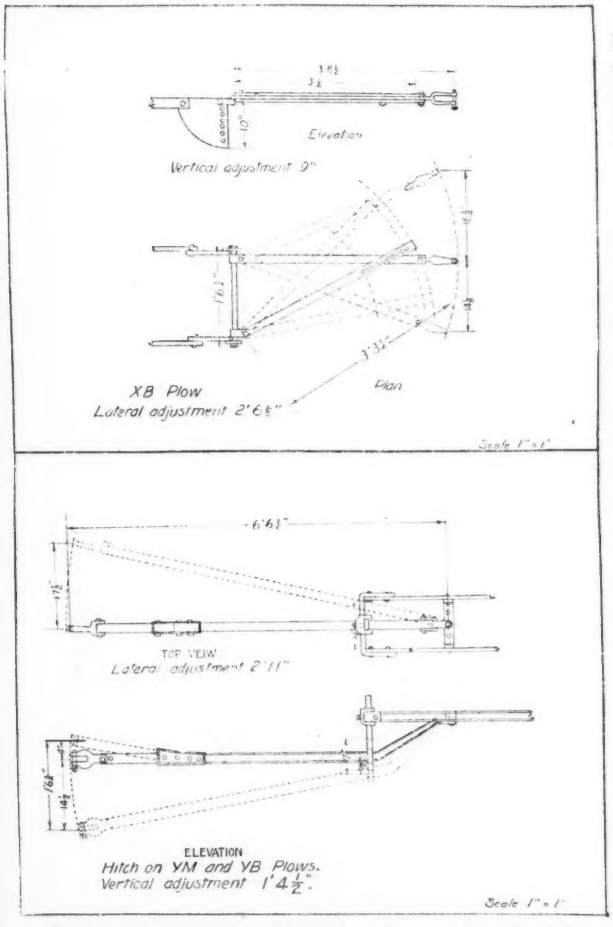
Instead of hitching the plow directly to the drawbar of the tractor, as was the case with Tractor B, the drawbar was moved to the right almost as far as it would go, and the hitch of the plow only slightly to the left. Then a 3-foot length of chain was used to couple the plow to the tractor. This practically eliminated side draft on the plow. The hitch was so made that it could be quickly dropped and the chain extended to 15 feet. In case of miring the tractor could run ahead to better footing, pull the plow through the soft spot, then back up to the short hitch. This method proved satisfactory and the work was finished in this way.

As the plow when making a full cut of 12 by 20 inches, sometimes gave a drawbar pull in excess of 2,000 pounds, it was thought that running in low gear might prevent miring. Several attempts were made to do this, but the interesting fact developed that the tractor mired far worse when running in low gear than in high. It would seem that the momentum of the higher speed, or the shorter time the machinery rested on the soft footing, permitted it to carry across the soft spots.

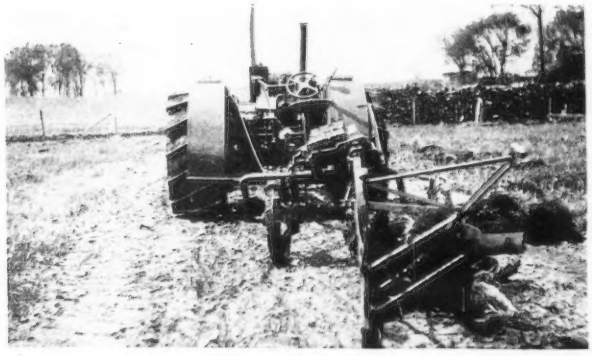
The widely spaced angle lugs and long spade lugs gave a much better grip on the sod without cutting it up than did the closer spaced angle lugs.

Tractor C did nearly all the later work. It was found that after the ground was harrowed and rolled, Tractor A would handle the drag harrow, the log drag, the Martin ditcher or any of the lighter machinery, but would not pull the heavy roller or the cutaway disk loaded to cut to a sufficient depth.

The first trial was made with a 20-inch XB standard breaker plow equipped with standing coulter. This was the same plow that was used with Tractor B in the early plowing, using a rigid hitch. In the tests, however, a chain hitch was used and one tractor so as to eliminate all variables such as speed and difference in hitch. In the tests the



Drawbar adjustment of XB plow above; YM plow below



(Above) This picture shows the offset of the XB plow
(Below) Offset of YM plow

TABLE II SPECIFICATIONS OF PLOWS

TYPE OF PLOW	Width of cut —inches	Weight —lbs.	Mounting	Length overall feet-inches	Throat clearance —inches	Drawbar adjustment	Length of share point to heel feet-inches	Length of landside feet-inches	Height of landside —inches	Height of vertical tangent —inches	Point of plow to top of moldboard —inches	Heel of plow to end of moldboard —inches
20-inch XB	20	1010	2-4-inch wheel	13-10	24	Triangular	2-9½	5-9	6	16	58	32
20-inch YM with furrow pusher	22	905	2-6-inch wheel	13-10	23½	Adjustable tongue	2-7	5-½	6	12	54½	27½
20-inch YM without furrow pusher	22	805	2-6-inch wheel	13-10	23½	Adjustable tongue	2-7	5-½	6	12	54½	27½
16-inch XB	16	927	2-4-inch wheel	13-10	24	Triangular	2-4½	5-9	6	11	55½	28
16-inch YB	18	805	2-6-inch wheel	13-10	23½	Adjustable tongue	2-1¾	4-4	3	11½	50	28

plow when cutting a 20-by-8-inch furrow developed a drawbar pull of 1350 pounds. At 10 inches deep the pull went up to 1500 pounds for a 20-inch furrow and 1650 pounds for a 22-inch furrow. At 12 inches deep and a 22-inch furrow the pull developed was 1800 pounds.

The 16-inch XB plow was a standard brush breaker. It was tested at 8 inches depth in firm peat and developed 1050 pounds pull. At 10 inches it developed 1350 pounds pull. In soft peat with a cut 10 inches deep the pull required was 1200 pounds. The furrow was 16 inches wide throughout.

The next plow used was a 20-inch YM marsh plow with furrow pusher and 24-inch rolling coulter. The center of the coulter was set 3 inches back from the point of the share and the cutting edge lacked 4 inches of penetrating as deeply. There was no adjustment which permitted deeper or more forward setting. In use soft roots were passed under the coulter in great quantity and clogged the throat with only a few feet advance. The rolling coulter was then removed and a standing coulter put in its place. All later work on the timbered peat was done with this type of coulter. It is doubtful if the rolling coulter would have been successful in this type of ground, even had adjustments been possible.

An explanation should here be made of what the sod or furrow pusher actually is. It is not, as may be at first supposed, merely a moldboard extension. It is a curved steel plate attached inside of the moldboard near the point of the plow and extending backward below and behind the moldboard on a level with the bottom of the furrow. At the back it is cross braced against an enlarged and strengthened landside. It was developed largely in cooperation with the agricultural engineering department of the University of Wisconsin purely as an aid in marsh plowing. Its purpose is to push the freshly turned furrow still farther to the right so that the next succeeding furrow will fall absolutely flat and then be pushed tight up against the preceding furrow, completely covering grass and litter.

The first trial with the plow was made with a rigid hitch. As previously stated, this method had to be abandoned When the drivewheels of the tractor dropped into a depression the beam of the plow was carried down with them burying the plow bottom and so increasing the draft that the tractor destroyed its footing and the whole outfit became mired.

In the trial with this equipment the sod cut was very uniform in size and the lay of the furrow slice very perfect Cutting a 24-by-12-inch furrow required a pull in soft peat of about 1650 pounds and in the dense, sodded peat an average of 1950 pounds.

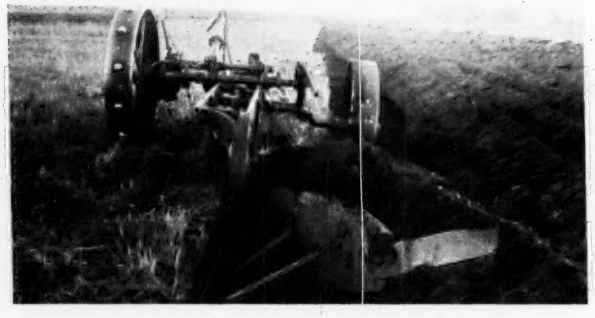
The same plow was then tried without the furrow pusher. The pull was an average of 1650 pounds both on the soft and firm peat. Comparing the pull of the plow with and without the pusher shows no increase in drawbar pull for the furrow pusher in the soft peat and 300 pounds where a solid furrow slice has to be pushed to one side. The increase in power required was more than compensated by the very much improved quality of work done.

During this trial the drawbar of the plow was also shifted to give a direct draft. The pull required dropped 150 pounds but the tractor could only with difficulty be held on the sod.

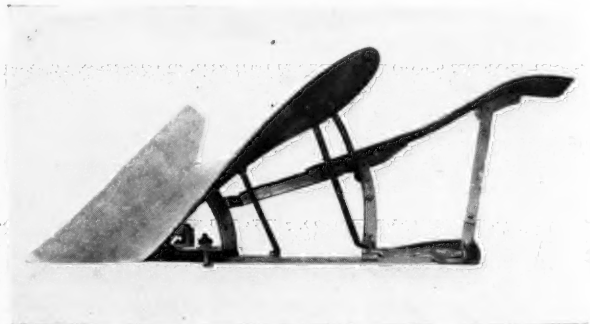
In all the trials with the 20-inch YM plow, it was noted that soil packed in the center of the curve of the moldboard particularly toward the front. Apparently this packing of the soil was due to a sharper curvature of the moldboard of this plow than of the others for the other plows did not clog in the same way and no change in hitch or adjustment of this plow made it scour through the center except where the sod was more than usually firm and dense.

The 16-inch YB plow was a standard brush breaker bottom applied to the same frame and wheels as the 20-inch YM. At 18 inches wide and 12 inches deep the pull was an average of 1250 pounds, while at 20 inches wide the pull averaged 1350 pounds.

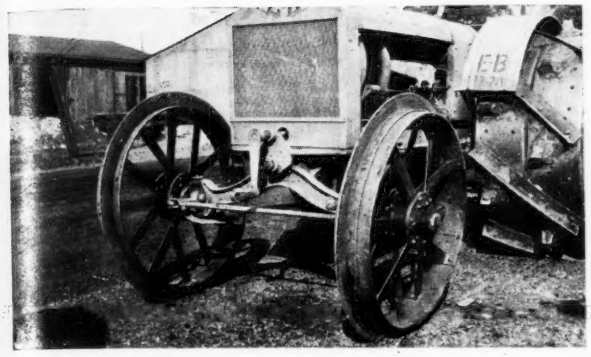
A very valuable implement for peat cultivation is the heavy roller for packing the seedbed. The one used was home made, the roller being of steel filled with concrete and having a steel frame. The diameter was 3 feet and length 4 feet. Total weight was 3500 pounds. When moving the



Oliver marsh (M) plow working in thin sodded peat. The plow is cutting a furrow 9 by 22 inches



Oliver marsh plow with furrow pusher. (Top view)



The E-B 12-20 tractor properly equipped for marsh plowing, with deep skid rings on the front wheels, and wide extensions, widely spaced angle lugs and spade teeth on the drivewheels

pull developed was an average of 950 pounds. It was noted, however, that when the roller stopped, it settled into the peat and in each case a pull of 2300 pounds was required to start it.

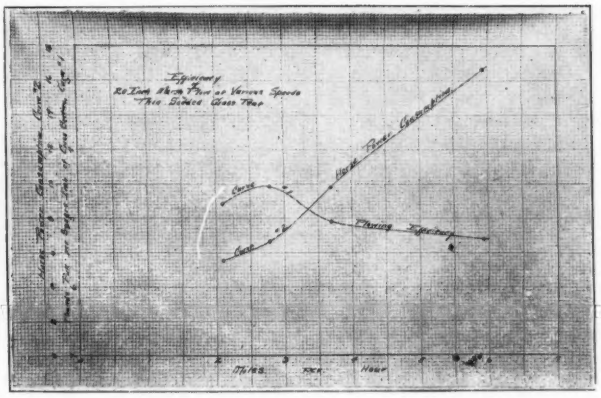
The cutaway disk proved itself very valuable in breaking up the seedbed. It was 5 feet in width with ten 16-inch disks. It had to be loaded with about 200 pounds in order to make it cut 7 inches into the ground. The pull developed was 1050 pounds, and 1500 pounds was required to start the load. This machine, even when loaded to make it cut deeply, would not do good work with one passage over sod land. Wherever the roots were heavy or strong the sod was not cut off in the bottom but was rolled over with the roots still hanging. Five passages were required to do only fairly decent work. On the turned sod, however or where there was no sod one passage gave very excellent results.

All of the other machinery used in cultivation was comparatively light and could be readily drawn with horses or a light tractor.

In order to get a comparison between the power required on timbered peat and that required on grass marsh, a level tract was chosen on which the vegetation was small sedge and grass. It was typical of the thinnest sodded peats in their natural condition.

TABLE III. POWER CONSUMPTION OF PLOWS IN TIMBERED PEAT

TYPE OF PLOW	Size of furrow —inches	Cross section— sq. in.	Drawbar pull —lbs.	Pull per sq. in. —lbs.	Speed in feet per minute	Drawbar horsepower
20-inch XB	20 by 8	160	1350	8.4	242	9.92
	20 by 10	200	1500	7.5	242	11.03
	22 by 10	220	1800	8.2	242	13.23
20-inch YM —with sod pusher in soft peat	24 by 12	288	1650	5.7	242	12.13
—with sod pusher in sod	24 by 12	288	1950	6.8	242	14.34
20-inch YM —without sod pusher in sod and soft peat	24 by 12	288	1650	5.7	242	12.13
20-inch YM —direct pull	24 by 12	288	1500	5.2	242	11.03
16-inch YB	18 by 12	216	1250	5.8	242	9.19
	20 by 12	240	1350	5.6	242	9.92
16-inch YB —firm peat	16 by 8	128	1050	8.2	242	7.72
	16 by 10	160	1350	8.4	242	9.92
16-inch XB —soft peat	16 by 10	160	1200	7.5	242	8.82
Maximum pull on plows			2400		242	17.64
Cutaway disk	60 by 7	420	1050	2.5	242	7.72
Roller			950		242	6.98



Efficiency and power consumption in plowing peat

The plow used was the 20-inch YM plow with rolling coulter and without furrow pusher. A direct pull was used. This plow on the timbered peat had given a drawbar pull of 5.2 pounds per square inch of cross section of furrow slice. Operating at the same speed and cutting a furrow slice 22 by 9 inches, the drawbar pull in the thin sodded open marsh was 4.54 pounds per square inch of cross section of furrow slice and the power expended was 6.68 horsepower. This is a decrease of only 12.7 per cent in favor of the thinly sodded peat and rolling coulter. On this ground because of the lack of deep or heavy roots the rolling coulter operated with distinct success.

The tractor was then operated at varying speeds to test out plowing efficiency. Four speeds in all were used of approximately 2½, 2¾, 3¾ and 6 miles per hour. It was found that the efficiency of the plow dropped with the slower speed and also with the higher, though in the latter case the greater drawbar pull must be offset against greater acreage plowed per day.

CONCLUSIONS

Several important things were brought out during the trials. What may be called the fundamental consideration upon which all the rest are built up was the better quality of work done by the heavier plows. This was later confirmed by the lessened weed growth on the deep plowing. During the summer nettles were plentiful on the shallow plowing but not on the rest of the field. The manner in which the land was later cultivated did not permit of tests for crop yield on the various depths. It is not assumed that deep plowing on new peat will help the crop yield the first year but practically the reverse.

There is no question, however, that it gets rid of the old growth and puts the land in better condition forever after. Throughout the whole test, the larger plows did better work than the small ones, giving a more complete turning of the furrow.

The rolling coulter as equipped was certainly not a success on the timbered peat, and it does not appear how it can be made a success on peat containing roots too heavy to cut or so soft that they would easily bend. These must be actually torn out of the ground to be gotten rid of. On open marsh sodded with shallow rooting small sedges and blue joint grass the 24-inch rolling coulter was a success.

TABLE IV. POWER CONSUMPTION OF PLOW AT VARYING SPEEDS—GRASS PEAT

(20-INCH YM PLOW CUTTING 22 by 9 INCHES.) SPEED		DRAWBAR PULL		Horsepower consumed
Ft. per min.	Miles per hour	Total	Pounds per sq. in.	
192	2.19	950	4.79	5.55
245	2.78	900	4.54	6.68
324	3.68	1000	5.05	9.82
522	5.93	1050	5.30	16.61

Possibly a smaller plow would also be satisfactory. In marsh containing reeds and the larger sedges, it would probably be necessary to have the coulter sufficiently large to penetrate below and forward of the point of the plow and so either cut off fibrous roots or carry them into the bottom of the furrow.

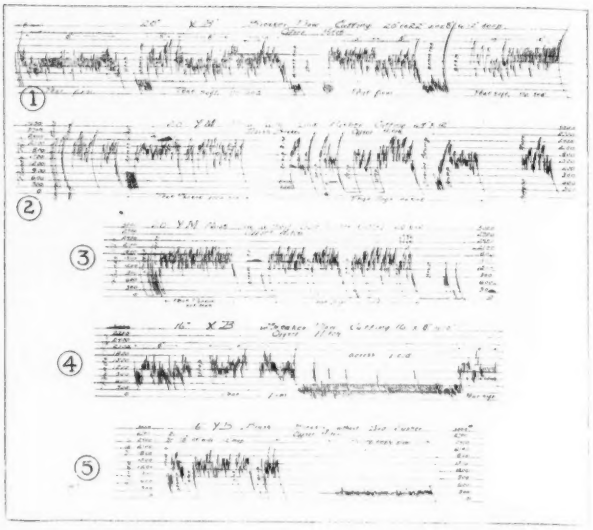
The furrow pusher was a distinct success. It did not add as much to the draft of the plow as was expected and it pushed the newly turned furrow out of the way permitting the more complete turning of the sod and elimination of top litter.

Analysis of the power consumption developed several interesting facts. On the larger plows the drawbar pull was quite constantly near or above 10 horsepower with reserve up to 17 horsepower drawn upon at times. For the smaller plows the power consumption was above 8 horsepower with a reserve up to 15 horsepower called upon. From this it would appear that for marsh breaking a tractor is necessary that is capable of developing not less than twelve working drawbar horsepower with a reserve above that. This power and reserve is not necessary for later plowing.

Ample support to the tractor proved to be just as important as power. Tractor B failed rather signally, not from any inherent defect in the design of the tractor itself or from lack of power, but because the special wheel equipment was not available which would enable it to do its work. It was like a strong swimmer thrown into the water and told to swim with a stone tied to his head and feet. It was capable of developing only about 1600 pounds pull without miring though able on hard ground to do much more. It not only mired its front wheels, but when the plow stuck, the closely spaced angle lugs on the drive wheels cut the sod, which was then thrown backward leaving the tractor mired. Tractor C had a much larger supporting area carrying less weight. The angle lugs were spaced twice as far apart as on Tractor B. It tore out its footing and mired quite uniformly when exerting a pull of 2400 pounds. This gave it 50 per cent more power in an emergency than Tractor B though Tractor C was of lower rating. The spade teeth served a very useful purpose in catching and holding submerged roots or timber in pulling out of a hole. The heavy skid rings gave the driver control of his machine on soft ground. This special equipment is not in any degree complicated or expensive. It can easily be made standard, to be attached to the tractor by the operator for soft ground conditions. There are many tractors now owned throughout the country which cannot be profitably operated in the early spring or in wet weather. This is especially true in the working of peat land. Yet peat land can be cultivated, even at its wettest without injury to the seedbed. It can be plowed in spring and seeded while the clay upland is still too soft. This is an extremely important factor in financing farming operations as well as general farm efficiency. It seems logical that the wider wheel equipment should be made standard for the wetter and softer districts and furnished upon the advice of the tractor dealer. It is also probable that in many cases where tractors are now unprofitable on soft lands that an expenditure of a hundred dollars would change an unprofitable into a profitable investment.

In calculating the power consumed per unit of cross sectional area the 16-inch plows give almost the same results as the 20-inch plows of the same make. This is not what was expected as it was thought that the vertical cut would offer a higher proportional resistance than the bottom cut. Apparently this was not the case, for the 20-inch plow gave no greater efficiency than the 16-inch of the same make.

There was an apparent advantage in efficiency in one make over the other. This is not thought to be due to any difference in design of the plow bottoms itself. In the case of the XB plow, however, the angle between the drawbar and the plow itself when working was 18 degrees and 20 minutes, while that of the YM and YB plows when working was 10 degrees, 38 minutes. Of the dynamometer pulls on the two plows, the horizontal components parallel to the line of draft were 5.33 pounds and 3.95 pounds per square inch of cross section of furrow slice. These figures compare favorably with the pull developed on the YM plow operating on thin sodded peat with direct pull but bring out the great loss in power through friction and otherwise due to the angle of draft of the offset hitch.



Dynamometer graphs of (1) 20-inch X3 plow; (2) 20-inch YM plow with sod pusher; (3) 29-inch YM plow without sod pusher; (4) 16-inch XB breaker plow; (5) 16-inch YB plow

The general proposition was established that for ordinary peat breaking the horsepower required can be figured readily and with fair accuracy on the basis of a five-pound pull per square inch of furrow slice. Multiply this by the speed it is proposed to travel and calculate horsepower in the ordinary way.

From the standpoint of mere efficiency in turning soil the cutaway disk loaded to cut 7 inches was far ahead of any of the plows. In fact its power consumption per unit of cross sectional area turned was less than one-half that of the plows. Its use is therefore strongly to be recommended under conditions where practicable. It cannot be recommended for first breaking instead of using plows for it required about five passages of the disk to give results equivalent to one plowing. The results of the work seem to indicate that disk machinery may be extremely efficient for all later cultivation.

The roller gave some remarkable results. Not only did it pack the peat and so form a better root bed but, after the ground had been plowed, harrowed and rolled, even that part which was originally so soft and full of holes that it was difficult to get the tractors through, it became sufficiently firm to support horses for all later cultivation.

The Problem of Traction

UNDOUBTEDLY one of the biggest single problems facing the tractor designer is the matter of efficient traction. Tests of tractors show that various machines will exert a pull on the drawbar from 30 to 93 per cent of their weight. Often the same machine will vary considerably on different soils. A careful study of the proper lug, or drive-wheel and track design will undoubtedly result in higher tractive efficiency. The swinging drawbar, and high steering bands on front wheels, have aided materially in the control of many of the smaller tractors.

The following is a complete report, including description of apparatus and methods of testing, of the California air cleaner tests.

Efficiency of Dust Separation in Air Cleaners for Internal Combustion Engines*

By Arthur H. Hoffman

Mem. A.S.A.E. Research Specialist, Agricultural Engineering Division, University of California Agricultural Experiment Station

ESPECIALLY in the arid and semiarid regions of the West and Southwest where the silicious character of the soils renders highly abrasive the dust arising around tillage implements at work, (Fig. 1), it has been found imperative to remove the dust from the air entering by way of the carburetor into the explosion chambers of internal-combustion engines. Where no air clarifier or one of low dust-separating efficiency is used, attrition of the internal working parts of the engine is so rapid that the useful life of the machine is sometimes reduced from a normal of 3,000 working hours to fifteen. This abnormally rapid wear (particularly in tractor engines) has considerable economic importance in agriculture in that it limits production by curtailing tillage and by increasing costs. In automobile engines, also, dust is often responsible for excessive maintenance costs and short life. This is particularly true in regions where dust or sand storms are frequent or where there is dense traffic on dry earth roads.

It has long been well known that air cleaners differ in their ability to remove the entrained dust, in the degree of vacuum their use entails, and in their effect on the power of the engine; yet there has been no publication of official tests from which to determine what performance might be expected from the several types and numerous makes on the market.

Measurements of vacuum and of power have long since been reduced to standard practice. The only novel features in connection with such measurements here reported are found in the methods employed to eliminate sources of probable error. In methods of determining dust-separation efficiency, however, there has been no established precedent. Tractor manufacturers particularly have realized the need of such information and many have made comparative tests. Much of such work done by test engineers in the employ of commercial concerns has been of good quality. However, there has been no uniformity in methods of testing, in the materials used to represent the dust encountered in the field, and in the degree to which errors arising from controllable variables have been eliminated. Hence the apparent efficiencies obtained by tests at different factories on the same make of cleaner have varied very widely. This might be expected when one takes into consideration that the materials used as the "dust" for the tests ranged all the way from air-floated Mississippi River silt to plain unsifted sand from the foundry rattler; that the dust was fed to the tested cleaner in some cases by use of very carefully designed and elaborately executed mechanisms, while in other cases a shovel was used; and that in some cases such variables as atmospheric humidity and hygroscopic moisture in dust were considered and their effects eliminated, while in other cases they were apparently forgotten.[1]

*Paper presented at the sixteenth annual meeting of the American Society of Agricultural Engineers, St. Louis, December, 1922.

NOTE: Several interesting lines of work in connection with air cleaners were not taken up at all or else barely touched. Among these are studies of how the following factors affect efficiency: (1) Rate of dust feed; (2) moisture content of the dust; (3) running the tractor along a steep hillside, particularly water type cleaners having floats; (4) the shaking an air cleaner gets on a tractor in use; and (5) the rate of water consumption and how shaking affects the rate of water consumption in water-type air cleaners, which should also be investigated.

NOTE: The author wishes to acknowledge his indebtedness to manufacturers who loaned apparatus and made helpful suggestions as to test methods, to members of other divisions of the University of California for equipment placed at our service, and to Profs. Fletcher, Thomson, and Moses who furnished counsel and active assistance in the testing work.

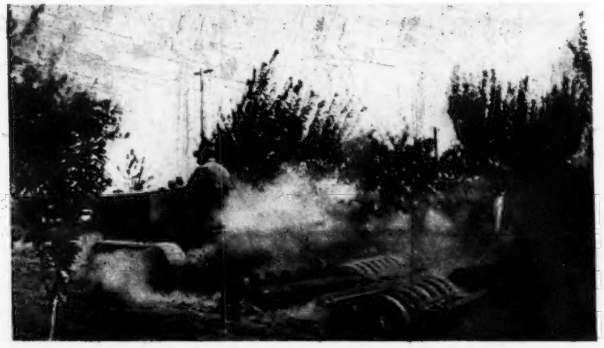


FIG. 1. Typical conditions under which the tractor in California must do its work. Dust and oil make a grinding mixture which quickly wears out many parts of a tractor

PART I. DEVELOPING A METHOD OF TESTING DUST SEPARATION EFFICIENCY

FIELD VERSUS LABORATORY TESTS

FIELD TESTS. It would seem at first glance that a very satisfactory way to get comparative efficiencies of several air cleaners would be to install them one after another on the same tractor doing the same work in the same field, using in series with the tested cleaner another which would catch all the dust passed by the first. There are several

[1] BIBLIOGRAPHY. So far as the writer is aware the only prior tests, other than those by manufacturers, were made by the Motor Equipment Section, Engineering Bureau, U. S. War Department, May 11 to 15, 1918, on two dry centrifugal type air cleaners. The report of the officer who conducted the tests has not been made available to the public. The following articles propose or describe methods of testing air cleaners:

"A New Form of Air Cleaner," by P. S. Tice, *Automotive Industries*, July 21, 1921.

"Suggestions from the Manufacturer of Air Cleaning Devices," by A. C. Bennett, *The Tractor Builder*, Dec., 1919.

"Instructions for Making an Air Cleaner Testing Outfit," by P. J. Dasey, *The Tractor Builder*, Dec., 1919.

reasons why such tests do not give an accurate comparison. Chief among them are the presence of certain factors, the variations of which cannot be controlled in a field test and which affect in some degree the efficiency of certain types and makes of cleaners. Varying from day to day and even from hour to hour are the following:

1. The wind velocity and direction with respect to the direction the tractor is moving.

2. The relative humidity of the air (varying from 6 per cent to almost 100 per cent in California), and hence the moisture content of the dust in the air.

3. The moisture content and other physical characteristics of the soil which affect its dustiness when tillage operations are carried on.

4. Aside from the foregoing sources of error, it is practically impossible to find anywhere a field of uniform soil and of sufficient area for conducting a long series of tests. If the *same* area is used, the increasing pulverization as successive tests are run causes denser and denser dust clouds to rise around tractor and implement. To illustrate, one tractor manufacturer reports having caught in the air cleaner in one 10-hour run as much as 10 pounds of dust. This was observed where the tractor milled around and around on the loam of the company's testing field. Over 1 pound caught in a day's work in an orchard has been reported by the engineer of one of the large land companies of this state. Usually the amount is much less.

To learn what could be done in a field test, a 25-horsepower tractor used in disking young orchards on the University Farm (California) was equipped successively with cleaner No. 23 (Bennett dry) and Cleaner No. 7 (Donaldson dry) in series with the "absolute cleaner" (described later) which was used in the laboratory tests. The Dailey air cleaner (same as No. 26), regular equipment on this tractor, was left in position. Thus the air entering the carburetor was cleaned first by No 23 (or No. 7), next by the absolute cleaner, and lastly by the Dailey cleaner. It is needless to say that the last cleaner caught no noticeable dust. The first test was run on Cleaner No. 23 set up as shown in Fig. 2. Conditions chanced to be such that the field efficiency checked rather closely the results obtained in the laboratory. A second test failed because the glass jar on this cleaner broke due probably to vibration. The third, fourth and fifth field runs were made on Cleaner No. 7 (Donaldson dry) set up similarly. The efficiencies were found to vary somewhat and to be considerably higher than the results of the laboratory tests. The two dry type cleaners were chosen principally because of the ease with which they could be attached for the test and the amounts of dust caught weighed. Fig. 3 is typical of the dust conditions prevailing during the field tests.

It is evident from the considerations before stated that reliable comparative values of efficiency of as many as twenty-six cleaners could not be had from field tests unless a very large number of tests, requiring several years' time should be run. Thus some of the cleaners tested would be obsolete before the results of the tests could be published.

LABORATORY TESTS. In the laboratory, on the other hand, a standard dust can be used which can be kept under identical conditions and fed to all cleaners in the same manner and at the same rates. Thus practically all the variables encountered in the field may be eliminated. A few check tests were run to determine the accuracy of the efficiency tests in the laboratory. One example is Run 127 (Table VIII) which was the duplicate of Run 125, the low water level test on the Donaldson air washer (No. 8). The two runs were one day apart, with somewhat different weather conditions and with different men operating the tractor motor, but with other conditions as nearly the same as possible. The efficiency in Run 125 is 95.0 per cent, as against 94.8 per cent in Run 127. This is 0.2 in 94.8 as against 2.8 in 73.8 for field runs F4 and F5 where conditions were as nearly identical as one could ordinarily hope to get them in a field test. However, since dust from field soils is highly hygroscopic, it is essential that care be taken to avoid running laboratory tests at times of high atmospheric humidity. Thus the original tests on Cleaner No. 23 which were run at a time of low humidity averaged about 3 per cent lower efficiencies than similar check tests run on the same cleaner in the midst of the wet season (relative humidity about 95 per cent). It should be stated, however, that a rather large adapter or shroud had to be placed around the inlet openings of Cleaner No. 23 to enable feeding all of a standard dust sample and not to interfere with the action of the cleaner. This gave the dust much better opportunity to absorb atmospheric moisture than would usually obtain. No. 23, being a dry centrifugal type cleaner, would be more efficient with moister and denser dust.

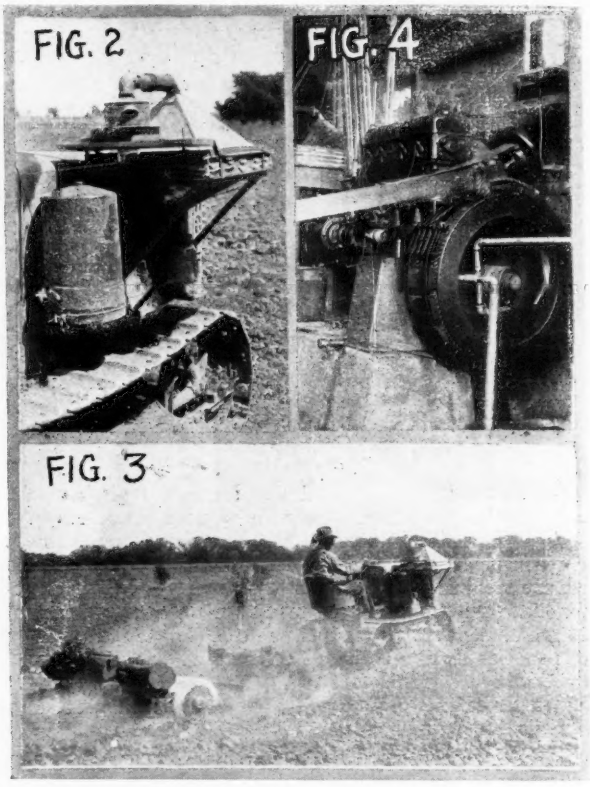


FIG. 2. Field test on Bennett dry cleaner (No. 23) happened to hit conditions of wind, air, and soil that gave a close check on efficiency tests run in the laboratory. A second field run failed because glass jar in base of tested cleaner broke from vibration. Other runs might have given somewhat different results

FIG. 3. FIELD TEST OF CLEANER EFFICIENCY
Typical of the dust conditions prevailing in the field tests. Cleaner No. 7 (Donaldson dry) under test

FIG. 4. Set-up of engine in the dust-separation efficiency tests run at Davis

A TRACTOR ENGINE USED IN THE TESTS. In order to duplicate field conditions as nearly as possible, it was decided to use a tractor engine instead of a large vacuum cleaner or other form of air pump to draw the air through the cleaners under test. A number of different makes of tractor engines would have been equally satisfactory for the purpose. The Weidely Model MAU engine used (Fig. 4) was made available for use without expense to

the University. This engine is four stroke cycle, four cylinder, vertical, valve-in-head, 3¾-inch bore, 5½-inch stroke, and 243 cubic inches piston displacement. Its S. A. E. rating is 22.5 horsepower. The 1½-inch Kingston Model L carburetor supplied with this engine was used throughout.

For the dust-separating efficiency tests made at University Farm, Davis, California, it was mounted on a concrete base and the load applied by a Prony brake and special brake wheel attached to the regular flywheel of the engine. The brake was constantly lubricated by a gravity oil feed and the brake wheel thoroughly water cooled, so that the load could be maintained at a constant value for considerable periods of time. The fuel was kept at a constant level. The regular governor on the engine was disconnected, speed regulation being accomplished by use of the throttle. The desired engine temperature was maintained by regulation of the flow of water from the service mains through the water jacket. Temperatures of incoming and outgoing water and of circulating oil were recorded as indicated by thermometers in thermometer wells of the usual type.

MEASURING THE RATE OF AIR FLOW. Rate of air flow was measured by a Venturi air meter especially built for the purpose. However, too much dependence should not be placed on the air-flow rate readings. It is reported by the U. S. Bureau of Standards that any air-measuring device of this or similiar nature is subject to considerable error when used to measure air flowing at an intermittent rate. There is available no satisfactory means of measuring accurately pulsating air flow without the use of enormously large and cumbersome equipment, impracticable for the laboratory tests herein described. Since the load on the tractor engine as measured by the dynamometer scales, together with the speed as indicated by a Hasler speed indicator, were depended on to determine equal rates of air flow, the inaccuracies that may be present in the Venturi meter readings do not in any way vitiate the results of the tests of dust-separation efficiency and of vacuum.

THE PROBLEM

The following items, which will be considered in order, constitute the problem:

1. To obtain a satisfactory standard dust.
2. To devise a proper mechanism for feeding the dust to the cleaner tested.
3. To find accurate means of determining the per cent of dust caught by the cleaner under test.

THE STANDARD DUST

REQUIREMENTS. The objective was to obtain a material in sufficient quantity for a long series of tests that would be fairly representative of the dust encountered in the average California field, and that would remain uniform and constant in composition and in its physical characteristics throughout the test series.

SOURCE. Fifty-pound samples of surface soil were obtained from ten tilled fields or orchards in the tractor-using areas of California. Table I gives the list of soils used and the amount of dust obtained from each. It should be observed that the list of soils shown in the table includes no volcanic ash.

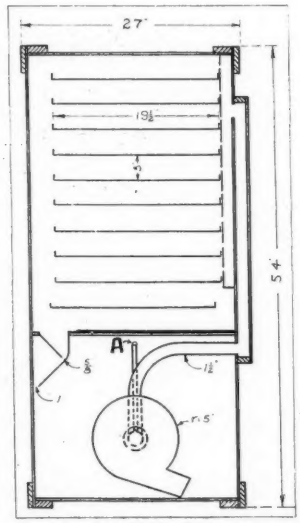


FIG. 5. Sectional view of device for air-floating a soil to obtain fine dust. Box fitted with tin shelves over which forge blower installed in lower compartment draws slow stream of dusty air. Pulverized, dried soil fed into fan and circulated violently in lower compartment. Two baffles at the left prevent passage of coarser, denser particles

SCREEN METHODS NOT PRACTICABLE. It was first intended to use screen methods to obtain the standard dust for the efficiency tests, but when it was found that of dust ordinarily caught in dry-type cleaners on the tractors in use in the fields of the University Farm over 99 per cent would pass a 200-mesh-per-inch screen, it was realized that screen methods would not produce a dust of fineness comparable with that which an air cleaner would encounter in the fields of this state. An air-floating process was then devised which produced a satisfactory material for the tests.

THE AIR-FLOATING PROCESS. The soils were separately dried at about 230 degrees Fahrenheit and pulverized by a process imitating the pulverization that might result from tillage processes but not breaking up the sand granules. After redrying and passing through a 16-mesh screen, the soils were fed through a funnel into the tube shown at A in Fig. 5. This conveyed the soil into the fan of an electric forge blower, whence it was blown into the lower compartment of the box and a part of it circulated again and again through the blower. A part of the air entering the blower came from the tube shown partly filling the fan intake. This tube drew a slow current of dust-laden air up past the two baffles, over the shelves, through the false back of the box, back to the blower. The baffles prevented heavy coarse particles from passing and the extremely slow air velocity over the shelves allowed much of the finer dust to settle out. The process was repeated until enough dust had been separated from a given 50 pounds soil sample.

RELATIVE DUSTINESS OF SOILS. The yields of air-floated dust for the several samples varied greatly, being least for the sands and most for the loams. The times spent in air-floating the several soils were not equal, hence the several yields shown in the Table I giving data of soils used in making up the No. 1 standard dust are not a true measure of dustiness. The order of dustiness as measured by yield in unit time is roughly the order in which the soils are listed in the table. Soil No. 1 yielded about twenty times as rapidly as soil No. 10.

TABLE I. SOILS USED IN MAKING NO. 1 STANDARD DUST

No.	Classification*	Field Located	From Town of	Lbs. air-floated dust taken from sample
1.	Holtville silty clay loam	2½ mi. S. and ½ mi. W.	El Centro	7.73
2.	Honcut silt loam	2½ mi. N. and 2½ mi. E.	Linden (near Stockton)	16.98
3.	Placentia loam	2½ mi. S. and ¼ mi. E.	Colton (near San Bernardino)	4.12
4.	San Joaquin fine sandy loam	½ mi. N. and 1 mi. E.	Klink (near Visalia)	3.54
5.	Yolo fine sandy loam	50 yds. W. of Prof. Dougherty's residence	U. F., Davis	2.57
6.	Yolo sandy loam	2 mi. S. and ¼ mi. W.	Davis	3.04
7.	Montezuma sandy loam	½ mi. N. and 2 mi. W.	Gardena (near Los Angeles)	4.98
8.	Goldridge fine sand	4 mi. W.	Taylor Station (near Santa Rosa	0.77
9.	Oakley sand	In townsite near Administration Bldg.	Delhi Settlement (near Merced)	0.61
10.	Madera sand	½ mi. N. and 1 mi. W.	Sanger (near Fresno)	5.48

Total air-floated dust, 49.82 pounds. This equals 99 per cent of No. 1 Standard Dust; 0.50 pounds.

Goldridge Fine Sand passed through 16-mesh screen equals the other 1 per cent.

Total weight No. 1 Standard Dust equals 50.32 pounds. All weights above are before drying.

*Classification by courtesy of Prof. Alfred Smith, Division of Soils, University Farm, Davis, California.

SIZES OF AIR-FLOATED PARTICLES. Readings taken with a micrometer microscope, sensitive to 0.0038 millimeters and 0.0175 millimeters per space, for the high and low-power nozzles, respectively, showed no appreciable difference in average size of dust particles between front, middle and rear of any shelf. The particles on the bottom shelf averaged about twice the size of those on the top shelf. There was a very wide range in size of particles. The minimum sizes were estimated at about 0.0003 millimeters (0.000012 inch), while some particles were as large as 0.16 millimeters (0.006 inch) in the longest dimension. A few vegetable fibers longer than 1 millimeter (0.04 inch) were observed.

Fig. 6 shows a part of the interior of the air-float box after the process is completed. In the case of loam soils especially, considerable dust was found adhering to the bottoms and outside edges of the tin shelves, as well as on top.

STANDARD DUST A COMPOSITE. The several air-floated dusts together with 1 per cent of Goldridge fine sand made up the No. 1 standard dust (Table I). This material was dried, thoroughly mixed in a revolving churn, redried, weighed out into 50-gram samples while hot, bottled at once, and the bottles stored in closed vessels with a dessicant until used.

PHYSICAL CHARACTERISTICS OF NO. 1 STANDARD DUST. Test shows 98.6 per cent of the No. 1 standard dust passing a 200-mesh screen. Its specific gravity, dry and loose, is 0.57. This may be increased to 0.68 by shaking down thoroughly. Chemical analysis shows 55.0 per cent silica (SIO_2) and 7.13 per cent "organic matter lost at red heat." (See Table II.)

A coarser, denser and moister dust would have given results much more flattering to cleaners of low efficiency, but would have made it very difficult, if not impossible, to differentiate properly between those of high and those of highest efficiency. (See Runs Nos. 127 and 128 in Table VIII.)

TWO STANDARD DUSTS. Two standard dusts were made up, known as No. 1 standard, which was used in all regular efficiency tests, and No. 2 standard which was used only in the "fill-up" tests. The No. 2 standard contains much coarse, dense material. It was made up by mixing the residues left from soils Nos. 1, 2, 3, 4, and 8, after the air-floating process. After being dried it was passed through a 16-mesh screen, mixed, placed in a closed vessel with dessicating material and weighed out as needed in the "fill-up tests" (described later).

FEEDING THE STANDARD DUST

FUNNEL NOT USABLE. It was first intended to use a modified hour glass to feed the No. 1 standard dust into the air stream entering the cleaner under test. When it was observed that the angle of repose was practically 90 degrees for the standard dust in quantities as large as the standard test quantity, other means were sought.

OTHER DEVICES. A device in use by the test engineers of one air cleaner manufacturing company stirs up a cloud of dust by agitating a quantity of material in a closed vessel, regulation of the rate of feed being by control of the compressed air jet which agitates the material. This and similar methods are open to the objection that lighter and finer particles will pass to the tested cleaner at the first of a test or of a series of tests and the coarser, denser particles later. The solution would seem to be a device that would feed *all* of a uniform standard sample at a uniform rate.

THE FEEDING DEVICE USED. In the device (Part C of Fig. 7) finally employed the standard 50-gram quantity of dust was placed in a sheet metal tube of rectangular section whence by means of a plunger it was pushed at a slow uniform rate against the edge of a bristle brush wheel revolved by a slow-speed electric motor. The brush wheel was placed in a housing through which passed the air entering the cleaner under test. An inner housing reduced to a minimum the

TABLE II. ANALYSIS OF STANDARD DUST

	Per Cent
Moisture lost at 105° C.	1.79
Organic matter lost at red heat	7.13
Loss of ash by acid treatment	5.36
Residual mineral matter	85.72
	100.00

Silica (SIO_2) in original dust, 55.0 per cent.

NOTE: Analysis made by Prof. P. L. Hibbard, University of California. The dust sent Prof. Hibbard was not dried before packing for shipment; hence the 1.79 per cent moisture content. The 50-gram standard portions were all rendered dry before being weighed and bottled ready for use.

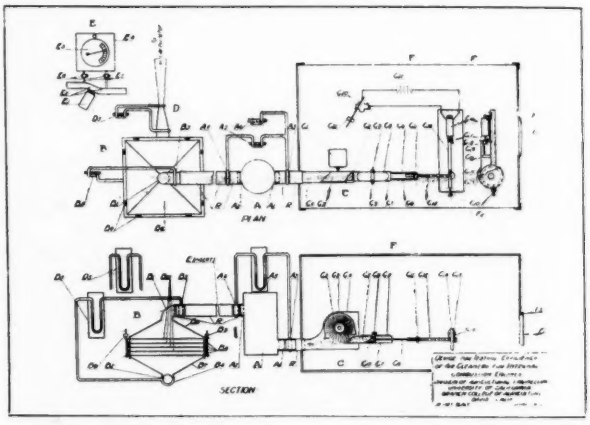


FIG. 7. General scheme of apparatus used in tests of dust-separation efficiency and of vacuum[2]

[2]KEY TO FIG. 7

A	CLEANER UNDER TEST
A1	Air inlet.
A2	Air outlet.
A3	Piezometer r'ng at inlet.
A4	Piezometer ring at outlet.
A5	Manometer for tested cleaner vacuum.
A6	Manometer for tested cleaner inlet vacuum.
B	ABSOLUTE CLEANER
B1	Absolute cleaner inlet.
B2	Absolute cleaner outlet.
B3	Inlet Piezometer ring.
B4	Outlet Piezometer ring.
B5	Absolute cleaner manometer.
B6	Absolute cleaner upper adapter.
B7	Absolute cleaner lower adapter.
B8	Wooden frames for absolute cleaner cloths.
B9	Clamp screws.
B10	Elderdown blanketing.
C	DUST-FEEDING DEVICE
C1	Slow-speed motor.
C2	Bristle brush wheel revolved by motor.
C3	Brush wheel inner housing (broken away in plan).
C4	Brush wheel outer housing (broken away in plan).
C5	Dust being fed to cleaner.
C6	Plunger connecting rods.
C7	Dust tube.
C8	Dust tube cover clamp.
C9	Dust tube cover clamp screws.
C10	Adjustable friction brake screw.
C11	Dust feed nut.
C12	Dust feed screw (pitches used—10,20,28 per inch).
C13	Dust feed plunger.
C14	Ratchet wheel (92 teeth).
C15	Electromagnet.
C16	Pawl.
C17	Armature.
C18	Armature adjusting screw.
C20	Electrical contacts.
C21	Pendulum of adjustable period.
C22	Storage battery, 32 volt.
C23	Pawl spring.
C24	Armature spring.
D	AIR METER
D5	Air meter manometer.
E	WATER AND SAND TRAP AND HYGROMETER
E1	Water and sand trap.
E2	Baffles.
E3	Hygrometer.
E4	Hygrometer box.
E5	Bypass tubes.
E6	Shut-off cocks.
F	CAGE FOR DUST FEEDING DEVICE
F1	Screen of elderdown blanketing.
F2	Door—part glass, part elderdown.
F3	Hand door.
R	RADIATOR HOSE FOR CONNECTIONS

centrifugal blower action of the brush wheel. The motion of the plunger pushing the dust column against the brush wheel was secured by a screw and nut, turned by a ratchet wheel, the pawl of which was moved by an electromagnet energized by current from a 32-volt storage battery. A contact pendulum closed and opened the battery circuit. The time for feeding the 50-gram standard sample could be made anything desired from about 15 minutes to 8 hours, by use of different feed-screw pitches and by varying the period of the contact pendulum.

General Scheme of Efficiency Test Apparatus. The apparatus used in the efficiency tests was set up as shown schematically in Fig. 7. The arrangement of apparatus in a typical test run is shown in Fig. 8.

No Dust Lost. At the close of each efficiency test run, the small amount of dust left in the tubes and housings was swept by use of small feather brushes into the ingoing air stream.

Filtered Air Used. To insure clean air being furnished, the dust-feeding mechanism was enclosed in a cage (F, Fig. 7) having a large part of its wall area made of eiderdown blanketing through which the air used was filtered. Since at the air velocities used this material is an almost perfect filter and since the room air was almost free from dust before being filtered, the error from this source was entirely negligible.

Adapters. In designing the connection between dust-feeding mechanism and the cleaner under test the constant aim was to avoid any construction which might affect the efficiency or vacuum of the cleaner. When a doubt arose one or more alternative constructions were employed. When results were sensibly the same using either construction, it was assumed that neither had appreciably affected the results.

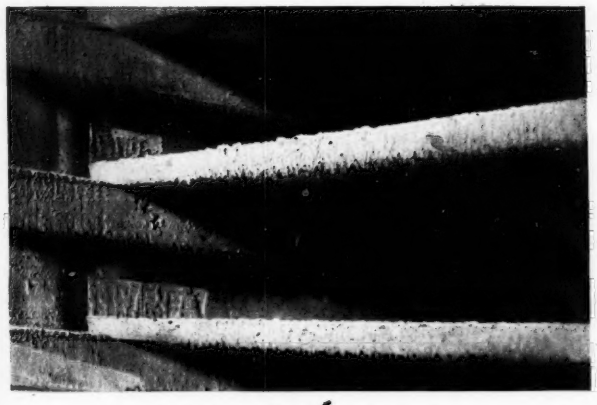


Fig. 6. Air-Floating Apparatus
Interior view of part of shelves. Dust ready to remove. Dust, from loam soils especially, collected on bottom and outside edges as well as on top of tin shelves

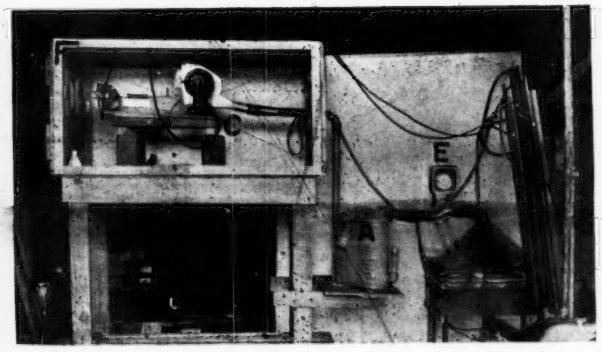


Fig. 8. Typical set-up for efficiency test of a water-type cleaner. A, the cleaner under test; B, the "absolute cleaner;" C, the dust-feeding device; F, cage to insure clean air coming to dust-feeding device. (Side of cage removed for photograph.)

Determining the Per Cent of Dust Caught by the Tested Cleaner

Weighing Cleaner Itself Not Practicable. Scales large enough to weigh the average air cleaner when ready for use are at best sensitive to one-fourth ounce (7+ grams). This is entirely too coarse to enable differentiation among the more efficient cleaners. Also in oil-type and water-type cleaners evaporation losses would introduce variable errors impossible to eliminate. Further, in two makes of cleaners tested, the dust removed from the entering air is ejected again into the open air, making the gross weighing method impossible. The alternative would seem to be to catch on accurately weighable material the dust passed by the cleaner under test.

The "Absolute Cleaner." This device (B, Fig. 7) consisted of two to six squares of eiderdown blanketing stretched nap side up on wooden frames, 18 inches square inside, which were solidly clamped between an upper and a lower sheet metal pyramid. While some dust was not caught by the absolute cleaner, the amount was generally less than 1 per cent of that entering it. In many tests the amount entering the absolute cleaner was less than 1 per cent of the 50-gram standard test sample. Further, a correction factor applied in each case added very closely the amount that would have been caught on the additional cloths if the number of cloths had been increased to infinity. Correction consisted in adding to the weighed total half the weight of dust caught on the bottom cloth. Since upwards of 90 per cent of the dust was generally caught on the top cloth, the correction addenda were very small.

Weighing the Eiderdown Cloths. The eiderdown cloths of the "absolute cleaner" were dried for not less than 2 hours at about 230 degrees Fahrenheit in an Emerson textile conditioning oven (Fig. 9) and weighed separately within the oven. The moisture absorbed from the air by the cloth and driven off in the oven, weighed in many cases more than ten times as much as the dust caught on the cloth. Moreover, the moisture content of the cloth varied with the humidity of the air; hence it was found very necessary to dry thoroughly before every weighing. Due to the currents of heated air rising from the textile oven while the weighings were being taken, the accuracy of weighing was not closer than about 0.01 gram.

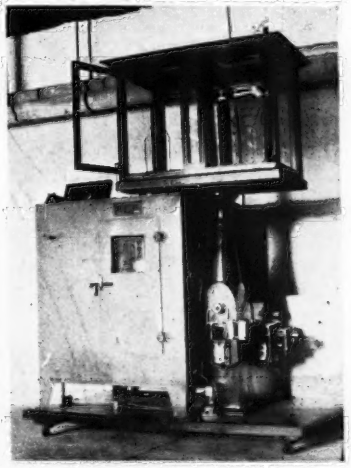


Fig. 9. Emerson Textile Conditioning Oven
Used by courtesy of Prof. J. F. Wilson, animal husbandry division, University Farm. Enables rapid and thorough drying and accurate weighing of the absolute cleaner cloths before and after use

Dust from soil also is highly hygroscopic. This necessitated drying the standard dust before weighing out the 50-gram samples.

Efficiency Tests

Three Standard Runs. Each cleaner received at least three test runs all at a normal engine speed of 1200 revolutions per minute and "quick dust feed" (50 grams in 30 minutes); first, a run at "normal load," about 20.4 horsepower; second, a run at "light load," about 12.6 horsepower; third, the "service run" in which variable load, variable

speed, quick pick-up with wide open throttle, idling and backfiring were features. At intervals during the service run, load and speed were brought to normal and manometer readings taken. The service test showed lower efficiency for a number of cleaners. As the service run follows closely conditions often found in practice, considerable importance is attached to the results obtained in it. For this run new cloths were used in the absolute cleaner so that they might furnish material for a satisfactory photographic record and for analysis of dust not caught by the tested cleaner. Fig. 10 is typical. (See also Figs. 30, 31, and 32.) One half of the top cloth of the absolute cleaner used in the service run was kept for reference. The other half was used in making determination of the amount of abrasive material (silica or sand) present. (Table IX.)

SPECIAL EFFICIENCY (AND VACUUM) TESTS. Besides the three standard efficiency tests, special tests were run in certain cases. These included a low-water-level test of cleaners of that type, a chaff test (Table VI) and a "fill-up" test (Table VII). The chaff test was run on those cleaners not having the intake adequately screened, and the construction of which was such that the presence of vegetable refuse would probably affect the vacuum. Ten grams of air-dry wheat chaff was sifted into the air stream and vacuum readings taken. The "fill-up" test was designed to test the ability of a cleaner to work under gross neglect and abuse. The results obtained by it are not regarded as being exact, but only as giving in a general way some idea of what might be expected of the cleaner when given no attention until it is filled up with dirt. As shown in Table VII, the rates of feeding the No. 2 dust were very rapid. It is possible that in some of the tests the results shown may be markedly different from what they would have been had the rate of dust feed been as slow as in the field. However, where a cleaner under this test took five or more pounds of the dust without appreciable rise in vacuum or loss of dust-separating efficiency, it is felt that the test had a real value and that the particular cleaner's ability to stand neglect has, in a measure, been established.

PART II. MEASURING VACUUM AND EFFECT ON POWER

VACUUM READINGS TAKEN DURING EFFICIENCY TESTS. Readings of vacuum due to the dust-feeding device, to the tested cleaner, and to the absolute cleaner were taken by open U-tube manometers at intervals throughout the efficiency tests. Distilled water was used in the manometers. No temperature corrections were made. Piezometer rings of conventional form were employed. (See Fig. 34 for variation of vacuum with quantity of dust taken in. See also summaries of fill-up tests and chaff tests, Tables VII and VI.)

POWER TESTS. Tests to determine the effects of air cleaners on the maximum possible power to be obtained from the engine were run on a Sprague dynamometer in the mechanical engineering laboratories of the University of California at Berkeley. The plan as carried out was designed to enable the taking of data by which a just comparison of the cleaners tested might be made. It is well known that the maximum possible power obtainable from an internal-combustion engine varies slightly in a short interval of time due to minute changes in the physical condition of its several parts, e.g., changes in viscosity of the crankcase oil due to changes in temperature or in amount of dilution with fuel condensing after escaping past the piston rings; changes due to wear or burning away of breaker points or spark plug points; changes in atmospheric temperature, pressure, and humidity. None of these variables can be controlled absolutely. Furthermore, power variations due to these causes are in some cases large enough to obscure entirely the slight effects produced by the use of the air cleaner under test. In the tests run controllable variables were controlled as far as practicable and the effects of the others were eliminated, at least partly, by taking three

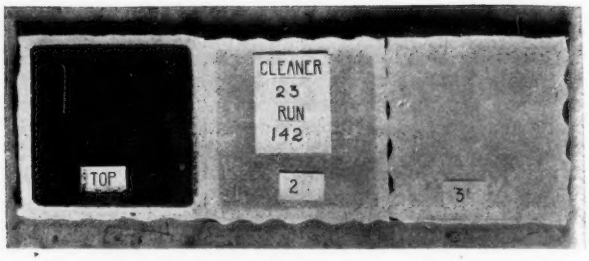


FIG. 10. PHOTO RECORD OF A SERVICE RUN
Cloths of absolute cleaner caught the dust lost by cleaner under test. One-half of each top cloth is filed for reference; other half is analyzed for silica content

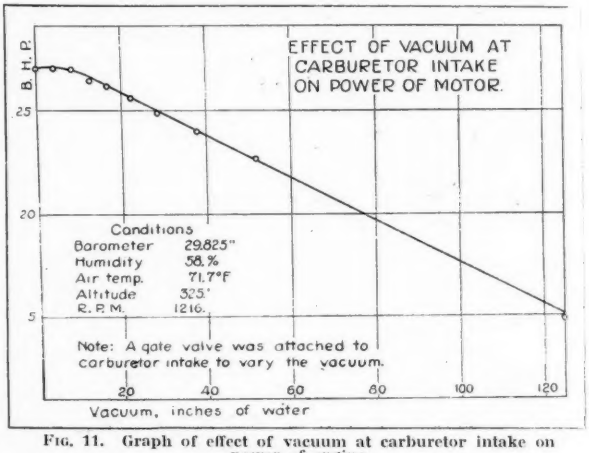


FIG. 11. Graph of effect of vacuum at carburetor intake on power of engine

sets of runs for each cleaner, as follows: One with cleaner off, one with cleaner on, then immediately another with cleaner off. The maximum obtainable horsepower with cleaner on, divided by the average of that of the two runs with cleaner off, in per cent, is taken as representing very nearly the effect we are striving to determine. In every case the engine was thoroughly warmed up by a preliminary run and fuel from the same tankful was used for the three sets of runs. The speed was held as closely as possible to a normal of 1200 revolutions per minute. To make sure that the needle valve of the carburetor was set for maximum possible power, many sets of readings were taken for slightly different settings of the needle valve, the speed in the meantime being determined by averaging large numbers of readings taken with a Hasler tachometer and being held to about the normal by changing the load imposed on the engine by the dynamometer. The results are shown in Table V and Fig. 35.

All the cleaners which had been in the dust-separation efficiency tests were cleaned out and reconditioned according to the manufacturer's directions before being used in the power tests.[3]

EFFECT OF VACUUM AT CARBURETOR INTAKE. In order to ascertain whether the effects of the several cleaners on the power of the engine were due only to the vacuum produced by them or to some other cause, a series of runs was taken beginning with the engine well warmed up and in good condition and the carburetor intake unobstructed. After maximum power had been obtained for this condition, a 1¼-inch pipe nipple, bearing a piezometer ring for attachment to manometer, was connected to the carburetor intake by a short piece of radiator hose and another series of readings taken. Next a 1¼-inch gate valve full open was attached

[3] In the case of one cleaner (Dailey, No. 26), it is very evident that the chaff from the chaff test had not all been washed out, as the vacuum observed was much higher than it had been for nearly the same power in previous tests. The showing would seem to do this cleaner an injustice, especially if, as reported, an adequate screen is to become a regular part of the equipment.

to the nipple and the readings continued, the vacuum being increased step by step by closing the valve until a vacuum measured by 124 inches of water had been reached. The results are shown in Table III and Fig. 11. The upper portion of the same curve is used in each of the four parts of Fig. 35. It will be noted that a slight increase of vacuum did not decrease the power and may even have caused a slight increase but that further increases of vacuum decreased the power nearly in direct proportion. It should be stated that this increase of power was probably due to the design of the carburetor. It is evident that had the intake tube of the carburetor been made a few inches longer, or of somewhat smaller diameter, the top of the curve would have been reached before any additional choking of the intake had been imposed. These tests must not be taken as determining the maximum possible power to be obtained from this particular engine since the exhaust from the engine was piped into an exhaust main which imposed considerable back pressure.

TABLE III—EFFECT OF VACUUM AT CARBURETOR INTAKE ON MAXIMUM POWER OBTAINABLE FROM AN ENGINE TEST RUN AUGUST 1, 1922

Engine, Weidely Model MAU; Dynamometer, Sprague Electric

Vacuum—Inches Water	0	4 1/32	8	12½	16⅜	22	28¼	37⅝	51½	124*
R.p.m.	1216	1219	1214	1219	1218	1217	1222	1218	1214	1210
Max. hp.	27.0	27.1	26.9	26.5	26.2	25.6	25.0	24.0	22.6	14.7

*9⅛" Hg.

NOTE: The values here given of Vacuum and Max. hp. were equated to uniform speed of 1216 r.p.m. before being plotted to make the curve of Fig. 33.

The power and vacuum for each cleaner as plotted in Fig. 33 were equated to the same speed. The horsepower value for each cleaner is obtained by multiplying 27 hp. (the open air value obtained in the gate valve test) by the cleaner's per cent of maximum power (cleaner on) divided by maximum power average (cleaner off).

It will be observed that the effects of the cleaners on power are very slight provided the cleaners are clean. So slight were they that in the cases of some cleaners the author is not at all sure that despite all our precautions and care the variations in power due to changes in the engine itself were not greater than those caused by the presence of the air cleaner. A few reruns were made but it was not deemed worth while to take the time to repeat all in order to correct a possible error probably at most only two or three-tenths of one horsepower in a total of 27. It should be remembered that all cleaners were cleaned out before the power tests. Had a few ounces of dust been in each the results for some of the cleaners would have been somewhat different. The graphs showing how amount of dust entering affects vacuum (Fig. 34) and how vacuum at carburetor intake affects power of an engine (Fig. 11) enable prediction of the probable effects of cleaners when a moderate amount of dust has entered. The latter graph holds only provided the carburetor is kept adjusted for maximum power. If not readjusted from time to time, increasing vacuum will enrich the mixture and so reduce power faster than the graph indicates. If on a 10-20 tractor the air intake is about three feet above ground, 150 grams of dust taken in in a ten-hour run may be regarded as about normal. More than eight times that much has been reported. A low intake and a high traveling speed make for larger amounts.

How the Work of the American Engineering Standards Committee is Conducted

THE American Engineering Standards Committee essays to serve as a national clearing house for engineering and industrial standardization, to act as the official channel of cooperation in international standardization, and to provide an information service on engineering and industrial standardization matters. The ultimate responsibility for and control of the work rests with the organizations whose representatives constitute the American Engineering Standards Committee. The process of industrial standardization may be conveniently divided into four stages, namely: (1) standardization by individual firms; (2) by societies and associations; (3) on a national scale; (4) on an international scale. The A. E. S. C., is primarily concerned with the last two stages. It is the agency through which industrial standardization in this country is passing from the second to the third stage, namely, from standardization by associations, societies and governmental agencies, to standardization on a national scale. Through its method and procedure, which are the result of extensive study and discussion on the part of numerous bodies concerned, and which have been further developed through three years of experience, the standardization work of the many bodies concerned is being broadened and unified into a system of national industrial standards.

The A. E. S. C. method is simply a systematic plan of cooperation by which all organizations interested in any particular standardization project participate (1) in deciding whether the work shall be undertaken at all, (2) in formulating the standardization, and (3) in its ultimate approval as an "American Standard" or a "Tentative American Standard."

The formulation of each standard, including all detailed work and technical decisions, is in the hands of a working committee, called a "sectional committee." The sectional committee is made up of representatives designated by the various bodies interested in the particular project in hand. Each sectional committee is organized by, and under the leadership of one or more of the principal bodies interested. Such bodies are known as "sponsors." This plan makes the committee the most decentralized of all national standardization bodies.

After the standard has been formulated and agreement upon it reached in the sectional committee, it is submitted, through the sponsor, to the main committee for approval. In acting on the approval of standards as "American Standards" or "Tentative American Standards" the main committee considers the adequacy of representation on the sectional committee of the various interests, and the procedure which has been followed, but it does not concern itself with the technical details of the standard. Hence, approval by the A. E. S. C. means not that the main committee has itself worked over and passed upon the technical details of the standard, but that it has satisfied itself that all organizations concerned have had an opportunity to participate in the work, that the work has been carried out under a procedure that has been regular, open, and above board, and that the standard represents a real national concensus on what is best in American engineering and industrial practice, and hence that it either already does or may reasonably be expected to play a significant, if not a controlling, role in the processes and materials in the industry concerned.

Agricultural Engineering Digest

Abstract of Current Literature on Engineering as Applied to Agriculture

Edited by **R. W. Trullinger**
Mem. A.S.A.E. Specialist in Rural Engineering, Office of Experiment Stations, U. S. Department of Agriculture

THE HEAT VALUE OF CORN, W. L. DeBaufre, [*Power*, New York, 56(1922), No. 6, p. 212.

In a contribution from the University of Nebraska, the results of studies of the heat value of four varieties of corn are reported. It was found that practically no difference exists between the heat values of the four varieties of corn, and that the heat content of cobs per pound is practically the same as that of the grain. The average higher heat value of dry corn was 8,159 B. t. u. per pound and of dry cobs 8,101 B. t. u. per pound. The average lower heat values were 7,579 and 7,577 B. t. u. per pound respectively.

There was a variation in the heat value, however, which depended upon the percentage of moisture the corn contained. "For fully cured corn containing, say, 10 per cent of moisture, the effective (lower) heat value is approximately 6,700 B. t. u. per pound. A corresponding value for Pittsburg, Kansas, coal is 11,800 B. t. u. per pound. Consequently, the heat value of 50 bushels of corn on the cob or of 63 bushels of shelled corn is about equivalent to that of one ton of bituminous coal. With coal at $10 a ton the price of corn on the cob must be less than 20 cents a bushel of 70 pounds and of shelled corn less than 16 cents a bushel of 56 pounds, to make it more economical to burn corn than to purchase coal. This comparison does not include any allowance for the cost of handling either fuel."

It is noted that a given amount of corn will produce more useful heat after storage than before, even though less weight of material is present owing to evaporation during storage.

FEEDING EQUIPMENT FOR CATTLE, W. A. Foster and R. S. Stephenson. (*Iowa Station Circular*, 75 [1922], pp. 31, figs. 28)—This circular describes, illustrates, and gives bills of material for equipment used in the feeding of beef cattle, with particular reference to conditions in Iowa. The equipment described includes banks, mangers, self-feeders, watering tanks, water storage tanks, cattle stocks, shipping crates, scale pens, dipping vats, silage carriers and carts, and feed lots.

EXPERIMENTS WITH INTERNAL-COMBUSTION-ENGINE FUEL, G. Kuhne. [Technik in der Landwirtschaft, Berlin. 3(1922), No. 8. pp. 189, 190. fig. 1.] Comparative studies of so-called "reichskraftstoff," an internal-combustion-engine fuel consisting of 52 per cent benzol, 34 per cent alcohol, and 13 per cent tetralin, with plain benzol are reported.

It was found that the composition fuel had almost as high a thermal efficiency as the pure benzol. No great difficulties were experienced in starting with the composition fuel except when the engines were very cold. Higher compression ratios could be used than with pure benzol.

SOME NOTES ON RAILWAY REFRIGERATOR CARS, W. H. Winterrowd. [Mechanical Engineering, (New York), 44(1922). No. 7. pp. 419-426. figs. 14.] This is a collection of what are considered to be the more important facts regarding the principles and methods involved in railway refrigerator car operation, and the types of cars and methods of construction used by various railways and private car owners.

The conclusion is drawn that while a very great improvement has been made in refrigerator car construction and design within the past few years, the field of investigation in connection with cars of this type is still a most fertile one. The construction of some fairly recent cars indicate that the subject of refrigeration in transit is not appreciated in some quarters as it should be. Efficiency in refrigeration is also considered to be quite important.

THE HOT SPOT METHOD OF HEAVY FUEL PREPARATION, F. C. Mock and M. E. Chandler. [Journal of the Society of Automotive Engineers, 11(1922). No. 1, pp. 27-32, 48, figs. 9.] On the basis of the belief that the sole requirement of satisfactory internal-combustion-engine operation with kerosene and mixtures of the heavier oils with alcohol and benzol is the proper preparation of the fuel in the manifold, the authors studied the various methods of heat application in an endeavor to produce the minimum temperature necessary for a dry mixture.

Finding that this minimum temperature varied with the method of application of the heat, an analysis was made of the available methods on a functional rather than on a structural basis. These included (1) the application of the heat from the walls of the manifold through the medium of the air, (2) application to the fuel alone or partly to the fuel and partly to the air, and (3) directing a spray of atomized fuel and air against a heated surface. A device is described by which the three main variables, the exhaust temperature, exhaust flow, and area of the heating surface may be regulated, and the three remaining variables, quantity of air, quantity of fuel supplied, and quantity of fuel vaporized, may be controlled.

Taking into account the wide range of temperatures that the air charge and fuel supply undergo before entering the intake-manifold system, a quantitative computation of heat transfer was made and the conclusions drawn that only by a combination of centrifugal force, surface tension, and the force of gravity can the unvaporized drops be separated from the fuel charge, and that the conditions of combustion are governed by the rate of fuel feed from the manifold to the cylinder and not from the carburetor to the manifold.

NEW DATA ON BURNING KEROSENE OIL IN HOUSE-HEATING BOILERS, J. Harrington. [Heating and Ventilating Magazine, Cooperstown, New York, 19(1922) No. 9. pp. 41-44, figs. 5.] The results of three series of experiments comparing coal burning, oil burning in a boiler designed for coal, and oil burning in an oil boiler are reported graphically and discussed. Both hard and soft coal were used.

The results were markedly in favor of oil burning in house heaters, both in boilers designed for coal burning and in those for oil burning. The best results were obtained in the oil-burning furnace both as regards uniformity and flexibility of heating. With anthracite coal the house

temperature varied from 60 to 80 degrees Fahrenheit during the experimental period and was rarely ever at the desired 68 degrees for more than a few hours at a time. The anthracite was not nearly so responsive a fuel as the soft coal. Considerably greater difficulty was encountered with both coals in bringing the house temperature from below up to normal than with oil.

It was further found that to get proper results with anthracite coal it must be burned under exactly the right conditions and that low rates of combustion are very inefficient. The cost of oil burning compared quite favorably with that of the best of coal burning.

WEARING TEST OF MANGANESE STEEL, SOFT CENTER STEEL, AND CHILLED CAST-IRON PLOWSHARES. [California Station Report 1921, p. 99.] Experiments by A. H. Hoffman are reported in which one share of each material was used on the same three-bottom tractor gang plow position, being interchanged after approximately one-third of each test had been run. The least wear was shown by the chilled cast-iron shares, slightly more by the soft center steel, and considerably more by the manganese steel.

TRACTOR AND PLOW REACTIONS TO VARIOUS HITCHES, O. B. Zimmerman and T. G. Sewall. [Journal of the Society of Automotive Engineers, New York, 11(1922), No. 1, pp. 107-115, figs. 17.] Some of the conclusions involved in the subject are enumerated and analyzed in part by the aid of diagrams and applied mathematics. Comparative draft data are presented in tabular form and discussed, as well as comparative hitch length data. Tractor reactions are explained in a similar manner, attention being given to the reactions on a slope and uphill. The factors involving tractor stability and resistance against overturn are also analyzed. These analyses are presented as a definite method of attack for the more correct solution of the proper hitching point and a study of lug design.

POWER LOSSES IN AUTOMOBILE TIRES, W. L. Holt and P. L. Wormeley. [U. S. Department of Commerce, Bureau of Standards Technologic Paper 213(1922), pp. 451-461, pl. 1, figs. 7.] Studies on the power losses or energy dissipated as heat in automobile tires when operated under different conditions of axle load, inflation pressure, speed, and tractive effort are reported.

The special equipment used consists of two electrical absorption dynamometers, one operated as a motor and carrying on its shaft a wheel and the tire to be tested and the other operated as a generator and carrying on its shaft a smooth, flat-faced metal drum. The motor is mounted on a movable carriage, the arrangement being such that the tire can be forced against the drum with a pressure corresponding to the desired axle load. In this way the tire and drum constitute a friction drive by means of which the motor drives the generator. The field pole frame of each dynamometer is supported in ball bearings concentric with the armature shaft and when in operation the magnetic drag or torque is measured on a scale. The power loss in the tire is the difference between the energy delivered by the motor to the tire and the energy delivered by the tire to the drum. This is determined from the speed of the motor and of the generator in conjunction with the torque on the respective field pole frames.

The preliminary results of these studies showed that in general the loss increases directly with an increase in speed or axle load, and it increases quite rapidly with a decrease in air pressure below the standard. Tractive effort had a comparatively small effect upon the power loss. There was a wide variation in the power loss in different tires run under the same conditions. Some makes of tires showed a larger power loss than others and fabric tires as a class showed a considerably greater loss than cord tires.

DUST EXPLOSIONS, D. J. Price and H. H. Brown. [Boston: National Fire Protection Association, (1922), pp. XX1+246, figs. 85.] This book is based on the work of the U. S. Department of Agriculture on the subject and gives the results of investigations, made by the Department through a period of several years, into the theory, nature, and causes of dust explosions of different kinds, and methods for their prevention. It is stated that all industrial plants in which a dust is produced in the handling of carbonaceous material or in the manufacture of various products from this material are subject to the possibility of an explosion.

The subject is approached by a consideration of what a dust explosion really is and of the different factors which affect its nature or behavior. The results of studies of what explosions have done and of the facts indicated by those which have occurred in the various industries are next presented, and measures are discussed which have proved most effective in preventing an explosion or in retarding its development when once started.

The book includes other chapters on industries producing dust and their extent, causes of dust explosions, and elimination of sources of ignition, prevention of explosions by control of explosive mixtures, phenomena of explosions, dust collection and removal, static electricity, explosions in grain-threshing machines, plant construction, cotton gin fires, coal-dust explosions, and review of explosions.

CRANKCASE OIL DILUTION PROBLEM AND ITS SOLUTION, W. F. Parish. [Journal Society of Automotive Engineers, New York. 11(1922), No. 1, pp. 35-47, figs. 14; also in Engineering World, 20(1922) No. 5, pp. 307-314, figs. 11.] This is an extended study of the effect of fuel dilution on the viscosity and, consequently, the efficiency of the lubricating oils in internal-combustion engines. The carbon-forming properties of oils and the effect of heavy oil on engine efficiency are discussed. Although the dilution of the lubricant should be a minimum with one engine operating at full load on the dynamometer stand, results of engine tests extending over the last ten years show an increase in such dilution of from two to twelve per cent.

As a solution of the problem of crankcase dilution, the author offers a system for crankcase oil regeneration consisting of four main elements by which the fuel and water dilution are removed automatically and the sediment composed of carbon particles, sand, and minute pieces of metal filtered out. The operation of this system, which it is claimed will not interfere with the present lubricating system of the engine and functions equally well with the splash and forced-feed systems, is described and illustrated. Charts showing the results obtained from comparative test runs with and without the system are also presented, indicating that its use practically eliminates crankcase dilution.

THE MECHANISM OF LUBRICATION, R. E. Wilson and D. P. Barnard, IV. [Journal of Society of Automotive Engineers, 11(1922), No. 1, pp. 49-60, figs. 11.] In a contribution from the Massachusetts Institute of Technology studies are reported, the primary object of which was to determine the fundamental mechanism of lubrication to serve as a basis for predicting the precise effect of the different variables under any specified conditions.

The conclusion is drawn that for any normal journal bearing operating in the region of fluid film lubrication, the coefficient of friction is not an independent function of the speed, the load, and the operating viscosity of the fluid at the operating temperature, but is rather a function of their combination in the form $z\,N \div p$, in which z is the viscosity, N the speed in revolutions per minute, and p the load on the bearing.

If the bearing and lubricant are both kept constant, all of the observed forms of the coefficient of friction were found to approximate a smooth curve when plotted against $z\ N \div p$. "Starting at very high values of $z\ N \div p$ and decreasing them, all the curves gradually approach a small value of f, generally in the neighborhood of 0.002. Before the ordinate axis is reached, however, the fluid film is ruptured, the coefficients rise very sharply, with a further decrease in the $z\ N \div p$ value and metal-to-metal contact and abrasion take place. The first region is termed the region of fluid film or perfect lubrication; the second, the region of partial lubrication. The intermediate point at which the coefficient is a minimum is the critical point of fluid film rupture."

In the region of perfect lubrication the relation of coefficient of friction to speed, load, and operating viscosity is not affected by the method of oiling or any variation in the oiliness of the lubricant. End leakage tends to give abnormally high friction for short bearings or those having very large clearances. Within the limits of good practice, the character of the bearing metal has no effect.

The use of smaller clearances tends to lower the critical value more than enough to counterbalance the increase in the coefficient of friction in the fluid film region. The use of lubricants of high oiliness tends to lower the critical point. Various bearing metals differ appreciably in their ability to maintain the fluid film at extremely low values of $z\ N \div p$.

In the region of partial lubrication viscosity is by no means the most important property of the lubricant, and the oiliness factor and character of the bearing metals come largely into play, the latter factor having an important effect on the friction. The coefficient of friction is no longer necessarily a function of $z\ N \div p$. The critical value of $z\ N \div p$ may be somewhat different for different combinations of the load and the speed, and may change with the temperature.

It is concluded that the only absolute limit to the carrying power of a given bearing is the pressure that will deform the bearing or seriously deflect the shaft. "The efficiency of a bearing should not, however, be judged on the basis of its carrying power nor by the minimum coefficient of friction at the critical point, but rather by the coefficient of friction obtained when it is operating with a reasonable factor of safety. The proper factor of safety will vary with conditions but as a general proposition the efficiency of a bearing can be measured in terms of the value of f obtained when operating at the value of $z\ N \div p$ which is five times that at the critical point."

LUBRICATION TESTS, H. T. Newbigin. [Engineering (London) 114(1922), No. 2957, pp. 260, 261, figs. 7.] Tests made with segmental, pivoted blocks or pads running against a plane surface, thereby providing the mechanical conditions necessary for the formation of true pressure oil films are described the load being applied while the bearing was running, thus eliminating any question of static friction. The apparatus consisted of a one-horse-power electric motor with vertical spindle. The bottom end of the spindle was carried in a Michell thrust bearing, and the top of the spindle was provided with a flat disk supporting a similar bearing on which the observations were made.

The purpose was to compare experimental results directly with the Osborne-Reynolds theory of lubrication. The tests were first run with pads pivoted behind their center of area in the proportion of 0.6 to 0.4. In the case of pads pivoted at or near the theoretically correct position, it was found that the results obtained experimentally were in remarkably close agreement with those calculated from pure theory. The tests made with centrally pivoted pads showed that not only did the results no longer agree with theory, but such pads are very much less efficient than the offset pads. Furthermore, the pads appeared to be in a state of unstable equilibrium when so pivoted. The details of the experimental apparatus are diagrammatically illustrated.

THE MEASUREMENT OF THE PROPERTY OF OILINESS, R. E. Wilson and D. P. Barnard. [Journal of Society of Automotive Engineers, New York, 11(1922), No. 2, pp. 143-156, figs. 17.] Studies conducted at the Massachusetts Institute of Technology are reported, in which a number of possible methods of measuring the property of oiliness and of throwing light on the mechanism of partial lubrication are described. The term oiliness is defined as that property of lubricants by virtue of which one fluid gives lower coefficients of friction, generally at slow speeds or high loads, than another fluid of the same viscosity.

The results of the preliminary studies with the methods described are taken to indicate that the static friction test, with proper refinements, is the best single measure of the properties of oiliness, but that it should be supplemented by measurements of the thickness of the adsorbed films at high pressures, in order to throw more light on the mechanism of the action of different constituents in lubricating oils. Animal and vegetable oils were found to be almost invariably superior in oiliness to straight mineral oils. Blending of these in proper proportions is said to improve greatly the oiliness of the latter.

The results are considered to confirm the hypothesis that oiliness is due to selective absorption of constituents in the oil by the metal surface, but the common conception of a monomolecular adsorbed film that acts merely by masking the attractive forces of the metal surfaces for one another appears to be incorrect. The adsorbed film is shown to be of colloidal rather than molecular dimensions, is a plastic solid rather than a fluid film, and apparently acts by smoothing over surface irregularities, carrying much of the load and minimizing metal-to-metal contact and abrasion. The structure and physical characteristics of this film seem to be more important than its thickness in determining its efficiency in lowering friction.

It was further found that the constituents of lubricants that form these adsorbed layers can be selectively adsorbed and largely removed from the oil by repeated treatments with very finely divided metals.

EXPERIMENTS ON CAPACITIES OF SOILS FOR IRRIGATION WATER, O. W. Israelsen and F. L. West. [Utah Academy of Sciences Transactions, 2(1918-1921), pp. 139-141.] This is an abstract of a report of experiments conducted at the Utah Experiment Station.

The observations show that an appreciable downward movement of water continued in each of three plats from June 14, the date of irrigation, to October 11, the date of the last sampling. The water was applied through small ditches in heads varying from 0.1 to 0.2 cubic feet per second. As soon as the water disappeared from the surface of the plats, an 8-inch straw mulch was applied to reduce evaporation.

The data show that a 12-inch application of water did not reach a 12-foot depth of soil for several days, but that some of the 24-inch application passed through the upper 12 feet the third day after irrigation and that much of a 36-inch application had gone below the 12-foot point one day after the water was applied. There was a gradual loss of water from the upper 6 feet of soil as the season advanced. The quantities of water found were not appreciably influenced by the depth of soil selected as the index of capacity. The rate of downward movement of water decreased rapidly after the fifth day after irrigation.

The maximum ratio of the moisture equivalent to the moisture content increased in the soil to which 12 inches of water were applied from 1.09 on June 20 to 1.17 on June 26,

and the minimum increased from 0.86 to 0.92, considering only the upper 6 feet of soil. The average ratio ranged from 0.98 to 1.05. The average maximum and minimum for the individual foot sections on the plats receiving 24 and 36 inches of water were almost exactly the same as for the plat receiving 12 inches.

THE RELATION OF THE METHOD OF ANALYZING ALKALI SOILS TO THE LIMITS OF TOXICITY, D. W. Pittman. [Utah Academy of Sciences Transactions, 2(1918-1921), pp. 95-99.] Studies are briefly reported which showed that different methods of determining the alkali content of soils gave widely different results, especially with reference to sodium carbonate, although the methods tried out in detail are about equally satisfactory in themselves as far as the toxic limits of alkali are concerned. It is concluded that in field studies it is necessary to use figures for the toxic limits which were determined by the same method of testing as employed in the work. Tables showing the toxicity of sodium chlorid, sodium carbonate, and sodium sulphate, as determined by four different methods, are presented.

ALKALI WATER FOR IRRIGATION, F. S. Harris and N. I. Butt. [Utah Academy of Sciences Transactions, 2(1918-1921), pp. 87-94.] In a contribution from the Utah Experiment Station a summary of information on the use of alkali water for irrigation is presented. It is stated that Utah waters are troubled mainly with sodium chlorid and sodium sulphate. Most of the waters of that state contain such small quantities of alkali salts that they are classified as good under ordinary conditions.

In pot studies it was found that on a loam soil without good drainage, wheat should never be irrigated with water containing as much as 1000 parts per million of sodium carbonate, and that even 500 parts per million will reduce materially the growth of the plants within three or four years. It was further found that water containing an appreciable quantity of sodium carbonate should not be used on heavy or impervious soils. A mixture of the chlorid, carbonate, and sulphate of sodium in equal quantities was not so harmful as the most toxic salt on loam soil but ranked high in this respect. Such a mixture was apparently stimulating when applied to the loam soil at the rate of 1000 parts per million during the third and fourth years, but for the first two years it was rather toxic.

Water containing 1000 parts per million or more of sodium chlorid was harmful to wheat or undrained loam soil in two years. Sodium sulphate applied at the rate of 4000 parts or more per million injured wheat on the loam soil in two or three years, but when added in a concentration of 1000 parts per million it did not appear essentially harmful in four years. Plants growing in soil containing sodium carbonate were very wasteful in the use of water, while those in soil containing sodium chlorid were more economical.

The length of culture did not appear to be so closely related to alkali as to other factors either in loam or in sand soil. In general, the number of spikelets per head decreased with increasing strengths of alkali. The weaker alkali, especially sodium chlorid and mixed salts, apparently stimulated the production of spikelets. The salts did not seem to be quite so toxic to the plants at a given concentration and time in the sand soil as in the loam soil.

An experiment with seedling plants showed the average order of toxicity for the different treatments to be sodium carbonate, sodium chlorid, magnesium chlorid, calcium chlorid, and sodium sulphate Solutions containing less than 60,000 parts per million of sodium chlorid apparently stimulated dry matter production in seedling plants. Sodium chlorid was slightly more toxic to growth in height of seedlings than other salts, and sodium sulphate distinctly favored this development. With the weaker strengths of alkali, the plants withstood sodium chlorid better than sodium carbonate, but when the stronger solution was applied the plants were killed at an earlier stage with sodium chlorid than with sodium carbonate.

These results are taken to indicate that the stage of growth reached by the plant before the alkali is brought into contact with it has considerable influence on the injury that will be done to it.

DISPOSAL OF MUNICIPAL SEWAGE AND ITS INDUSTRIAL UTILIZATION, Keppner. [Die Technik in der Landwirtschaft, and published by Verein Deutscher Ingenieure, Berlin, 3(1921), No. 3, pp. 53-58, figs. 4.] This report describes the use of sewage and sewage sludge for irrigation and fertilization purposes as they are practiced in different parts of Germany. It deals especially with purification by surface irrigation and spraying on agricultural soils and with purification in fish ponds.

It is stated that some of the difficulties attending the use of direct application of the sewage to the soil are that large fields fitted for the purpose are usually too far distant from cities. The cost of the piping and spraying system is usually high, and the soils are not always adapted for a continuous absorption of the sewage.

In the process of sewage purification in fish ponds, it has been found that at least 50 per cent of all suspended matter must first be separated and the thus mechanically clarified sewage must be diluted with from three to five times its quantity of pure water. Decomposed sewage must not be introduced into a pond, and all fatty substances should be previously separated from the sewage. Carp and tench, and in certain cases rainbow trout, have been found to be the best fish for this process. It is noted that, contrary to the usual opinion, fish do not eat sewage. The cycle of sewage purification in ponds has been found to consist of bacterial action, protozoan action, and the action of plants and higher animals, such as crabs, worms, and insect larvae.

The application of fresh sludge to soil is also discussed, and the sewage disposal system of the City of Munich, which disposes of the greater part of the municipal sewage by application to the land, is briefly described.

THE PRINCIPLES OF MECHANICAL REFRIGERATION, H. J MacIntire. [New York and London: McGraw-Hill Book Company, Inc., 1922, pp. VIII—252, figs. 114.] This book is intended as a study course for operating engineers and covers the entire field of refrigeration in an elementary manner. It contains chapters on the compressor; condensers, ammonia piping and accessories; other refrigerating systems; erection and operation; refrigerants; heat transfer; piping and piping calculations; ice making; and applications of refrigeration.

MOMENTS AND STRESSES IN SLABS, H. M. Westergaard and W. A. Slater. [American Concrete Institute Proceedings, 17(1921), pp. 415-538, figs. 68; also National Research Council, Reprint and Circular Series, No. 32(1921) pp. 124, figs. 68.] This is a contribution from the University of Illinois and the U. S. Bureau of Standards. Its purpose is to present information which correlates the results of tests of a fairly large number of slab structures with the results of analysis to aid in the formulation of construction regulations for slabs. The report is divided into an analysis of moments and stresses in slabs, a study of the relation between the observed and the computed steel stresses in reinforced concrete beams, and a study of the test results for flat slabs with a view to comparing the moments of the observed steel stresses with the bending moments indicated by the analysis and of estimating the factor of safety. A bibliography is appended.

A. S. A. E. and Related Activities

McCrory Urges National Program Of Land Utilization

S. H. McCrory, chief of the division of agricultural engineering of the U. S. Department of Agriculture, and the representative of the American Society of Agricultural Engineers on the American Engineering Council, the executive arm of the Federated American Engineering Societies, at a recent meeting of the American Engineering Council urged that a national program of land utilization be adopted. Mr. McCrory's statement is substantially as follows:

The easily developed tillable land of the United States has nearly all been brought into use The lands that remain to be made available for cultivation require considerable expenditure for clearing, drainage or irrigation before they can be made available.

In the past land development and utilization has depended largely upon local initiative. Apparently the time is approaching—if indeed it has not already arrived—when consideration must be given to the probable needs of the United States for crop lands, pasture lands, and forest lands. At the present time we are harvesting the stored timber which has been decades in growing.

The time is not far distant when this supply will have been largely exhausted, and we must either import or grow timber to supply our needs. Apparently there is no large supply of nearby timber available for importing.

If we are to grow our timber, a considerable acreage must be permanently devoted to this purpose. At what rate should our swamp, arid, and cut-over lands be reclaimed and made available for cultivation? What area of land can most profitably be devoted to the growing of crops, of livestock, and of timber?

Careful consideration should be given to the utilization of our undeveloped lands in order that they may be put to the most efficient use. There is no advantage in bringing under cultivation land that is suited only for growing timber, and then after it has been found unprofitable for cultivation, allowing it to go back to timber again. Neither is it desirable to reclaim lands much in advance of their settlement.

If the present American standard of living is to be maintained, careful consideration must be given to the most effective utilization of our undeveloped lands in order that the large amount of waste which has occurred in the past due to poorly planned attempts to utilize lands may be avoided.

Student Branch Activities

Ohio State University

THE student branch of the A. S. A. E. at Ohio State University reports considerable progress during the present school year. Five regular meetings and one open meeting were held during the winter quarter. The most important business receiving the attention of the branch was the resolution to the faculty providing that men majoring in agricultural engineering be permitted to take thirty hours of mathematics, fifteen hours of physics, and ten hours of mechanics, this work not now being allowed toward graduation in the college of agriculture. The resolution also provided that the standards of the present course in agricultural engineering be raised, and at the end of two additional years work (a six-year course) the student be given the M. E. degree and the professional degree of agricultural engineer. This arrangement will allow the student to fulfill the present curriculum of the college of agriculture with the exception of the courses in zoology and entomology.

During Farmers' Week, January 29 to February 2, the student branch furnished meals to the visitors at the tractor show, clearing about $125.00, which will help greatly in carrying on the work of the branch. The tractor show was a great success, six tractors being tested; members of the student branch conducted the tests.

February 22 the branch held an open meeting and smoker in conjunction with a motion picture show. Fifteen members were added to the organization at this meeting, making a total enrollment of fifty members at the present time.

On March 13 Don W. Griffin, a member of the parent society, and agricultural engineer to the Rajah of Gwalior, Central India, talked to the branch on conditions in Central India from the agricultural engineer's point of view.

Other meetings were well attended, the faculty members of the department of agricultural engineering addressing the meetings on subjects of special interest.

Agricultural Engineer Elected To Phi Beta Kappa

ERNEST Haight, a student in the agricultural-engineering course at the University of Nebraska, and an A. S. A. E. student branch member at that institution, instead of completing his agricultural-engineering course in 1923, registered in the arts college in September 1922, and will receive his A. B. degree in June, 1923.

The part of particular interest in this conjunction, and particularly to the agricultural-engineering faculty of Nebraska, is the fact that Mr. Haight in the process of taking work in the Arts College was elected to Phi Beta Kappa, a distinct honor under the circumstances. In September 1923 Mr. Haight will again register in the engineering college and complete his work for a degree in agricultural engineering.

New Members of the Society

C. O. Aspinwall, assistant manager, experimental department International Harvester Company, Chicago, Illinois.

Nils Berglund, department of agricultural engineering, Iowa State College, Ames, Iowa.

R. H. S. Henderson, service engineer, Advance-Rumely Thresher Company, La Porte, Indiana.

Arthur Huntington, sales engineer, public relations department, Iowa Railway & Light Company, Dows Building, Cedar Rapids, Iowa.

Roy B. Johnston, superintendent of experiments, West Pullman Works, International Harvester Company, Chicago Illinois.

Transfer of Grade

Rudolph H. Driftmier, department of agricultural engineering, Kansas State Agricultural College, Manhattan, Kansas. (From Junior Member to Associate Member.)

Applicants for Membership

The following is a list of applicants for membership received since the publication of the May issue of Agricultural Engineering. Members of the Society are urged to send pertinent information relative to the applicants for the consideration of the Council prior to election.

Harold T. Boyle, Jackson, Nebraska. (Transfer from Student to Junior Member.)

Orville Brown Byram, Waverly, Iowa. (Transfer from Student to Junior Member.)

Kay I. Church, 223 S. Wichita Street, Wichita, Kansas. (Transfer from Student to Junior Member.)

Merl Stanley Cook, 1408 Fairchild Street, Manhattan,

Kansas. (Transfer from Student to Junior Member.)

John Gustave Gilson, 143 Lincoln Way, Ames, Iowa. (Transfer from Student to Junior Member.)

R. G. Hemphill, irrigation engineer, U. S. Department of Agriculture, Federal Building, San Antonio, Texas.

C. N. Johnson, general engineering department, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania.

David Junkin, RFD No. 2, Natchez, Mississippi. (Transfer from Student to Junior Member.)

Ernest Winfred Trussell, Booneville, Mississippi. (Transfer from Student to Junior Member.)

Sturges L. Victor, 429 Lincoln Street, Onarga, Illinois. (Transfer from Student to Junior Member.)

EMPLOYMENT SERVICE

This service, conducted by the American Society of Agricultural Engineers, appears regularly in each issue of AGRICULTURAL ENGINEERING. Members of the Society in good standing will be listed in the published notices of the "Men Available" section. Non-members, as well as members, are privileged to use the "Positions Available" section. Copy for notices should be in the Secretary's hands by the 20th of the month preceding date of issue. The form of notice should be such that the initial words indicate the classification. No charge will be made for this service.

The Secretary receives at frequent intervals bulletins from the Engineering Societies' Service Bureau, 29 West 39th Street, New York City, listing the "positions open" as reported by member societies. Copies of these bulletins are sent to the "men available" listed below, as soon as received.

Men Available

MECHANICAL AND ELECTRICAL ENGINEER, graduate of Cornell University and Armour Institute, with nineteen years of practical experience in designing, manufacturing, and marketing gasoline engines, automobiles, motor trucks and tractors, having specialized particularly on internal-combustion motors and their application, prefers mechanical work cooperating with the different manufacturing and sales departments along the lines of sales engineering, or other work into which his qualifications would fit. MA-104

AGRICULTURAL ENGINEER wants position in southwest. Graduate of University of Illinois 1915, five years practical experience on Illinois farm with power equipment, two years in charge of the agricultural engineering department New Mexico College of Agriculture; considerable garage experience and service experience on unit power and light plants. Also one summer in Philadelphia battery service station. MA-106

AGRICULTURAL ENGINEER, graduating from Iowa State College June 10, 1923, would like position with some company or individual engaged in drainage or irrigation work. Five years' practical farm experience. MA-118.

AGRICULTURAL ENGINEER, graduate in mechanical engineering at Michigan Agricultural College, desires position teaching all kinds of farm machinery or automotive work, or with some farm-equipment manufacturer. Will be available April 1, 1922. Has served one year as instructor in tractors and trucks, and one year conducting service schools for a leading tractor manufacturer. Can furnish best of references. MA-110

GRADUATE AGRICULTURAL ENGINEER, now employed by tractor company, wishes position teaching agricultural engineering work. Will be available in summer or to start next fall. MA-115.

AGRICULTURAL ENGINEER, graduating from University of Illinois at end of present semester (available March 1, 1923) would like position in service department or experimental department of company manufacturing tractors or farm machinery. Three years' practical farm experience in West and one year in Illinois. Age 27. Unmarried. MA-116.

DEVELOPMENT AND RESEARCH ENGINEER, technical graduate, inventive ability, practical, experienced in the development, design, manufacture, and distribution of farm machinery. Can carry through from the embryo idea, through development stages, production in manufacturing, and marketing. Age 29. Married. Excellent character. Available immediately. MA-117.

Positions Open

DRAFTSMAN who has had experience in designing and manufacturing threshing machinery with reliable, well-established farm-machinery manufacturer in central Pennsylvania. PO-1.

STUDENT FELLOW IN AGRICULTURAL ENGINEERING. There will be an opening beginning September, 1923, for a student fellow in agricultural engineering at the Virginia Polytechnic Institute. Write Charles E. Seitz, department of agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Virginia. PO-4.

INSTRUCTOR IN AGRICULTURAL ENGINEERING. The department of agricultural engineering of the Virginia Polytechnic Institute has an opening for an instructor to handle farm surveying, farm buildings, farm concrete, and rural architecture. He will also devote part time to extension work. Write Charles E. Seitz, department of agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Virginia. PO-5.

Directory of Professional Agricultural Engineers

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AMES, IOWA
Editor, John Wiley & Sons, Agricultural Engineering Series of Technical Books
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Inspections, Investigations, Tests, and Reports
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Wanted—Correct Addresses of These A. S. A. E. Members

NOTE: Mail is being returned from the addresses given below. These members, or others who know of their whereabouts, are requested to send the Secretary their correct addresses at once. Inasmuch as delivery cannot now be made, AGRICULTURAL ENGINEERING will not be mailed until correct addresses are received.

Nelson C. Beem, Carey, Ohio.

X. Caverno, Kewanee, Illinois.

R. D. Chapman, 1336 Woodward Avenue, Detroit, Michigan.

George M. Duncomb, 136 S. Harvey Avenue, Oak Park, Illinois.

J. C. Elliff, Box 115, Little Rock, Arkansas.

H. A. Hatfield, Bank of Hamilton, Toronto, Ontario, Canada.

W. R. Killinger, 108 S. Franklin Avenue, Riverside, Illinois.

H. D. Lewis, Box 146, State College Station, North Carolina.

M. W. McDonald, Charleston, West Virginia.

John T. Montgomery, Bliss, Oklahoma.

Arthur H. Pearsoll, 1350 Rosedale Ave., Chicago, Illinois.

Jose Rivera, Matamoros 23, Mexico City, Mexico.

F. K. Runyan, 187 Peachtree St., Atlanta, Georgia.

George W. Rynders, Box 127, Bradley, Illinois.

Lee Stewart, Spooner, Wisconsin.

J. H. Stowell, 3500 Colfax Avenue, South, Minneapolis, Minnesota.

S. Y. Sweeney, 111 East Campbell Avenue, Roanoke, Virginia.

T. A. Toenjes, 1115 South Street, Waterloo, Iowa.

L. R. Van Volkenberg, Box 642, Fargo, North Dakota.

J. C. Weidrich, c/o Dempsey Hotel, Davenport, Iowa.

George G. Whitfield, Demopolis, Alabama.

A. A. Wolf, Y. M. C. A., Omaha, Nebraska.

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IT IS not necessary to pile bags of dirt, rocks or other extra weight on top of the Oliver tractor disc harrow in order to obtain good results in hard, lumpy soil. Penetration is obtained in this harrow by design rather than by unnecessary weight. The draw bars are fastened to the upright brackets above the disc bearing and the tractor hitch is below the pivot bearing which connects the rear and front gangs. This design creates a downward pull on the cutting edge of the discs and causes the harrow to cut deep even in hard, lumpy soils.

Irregular conditions in the field are easily handled with this harrow by means of a conveniently located screw device which controls the angle of the gangs. Only a few turns of this screw are necessary to increase or decrease the penetration to correspond with the condition of the soil. And it is not necessary to have the harrow moving in order to make this change.

These features combined with light draft have created a great demand for the Oliver disc harrow among tractor owners.

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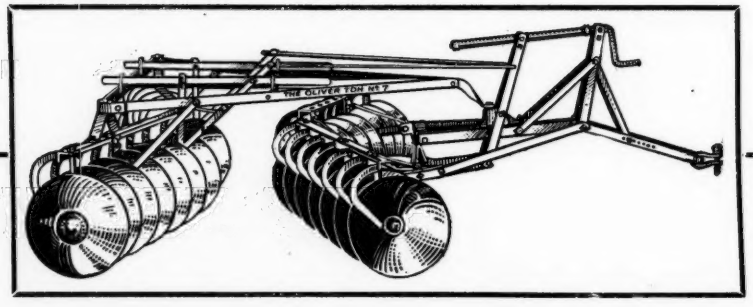
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